A Summary of Current Program, 4/1/63 and Preliminary Report of Progress for 4/1/62 to 3/31/63

AGRICULTURAL ENGINEERING RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued between April 1, 1962, and March 31, 1963. Current agricultural research findings are also published in the monthly U.S.D.A. publication, Agricultural Research. This progress report was compiled in the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE
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INTRODUCTION

Agricultural Engineering Research as used in this report is concerned with the applications of engineering principles to agricultural production and rural living. More specifically, it deals with the power, machines and structures required, and includes (a) development of new and improved equipment for the more effective mechanization of seedbed preparation, fertilization, planting, cultivation, pesticide application, harvesting and farm handling of crops, and studies of the more efficient use of such equipment; (b) development of more effective and lower cost buildings and equipment for the handling and sheltering of livestock, including research in functional requirements; for the handling and storing of farm commodities on the farm, and for farm living; (c) development of more effective methods and equipment for the mechanical preparation and conditioning of farm products for farm use or sale, including such testing and quality determination as needed to adequately evaluate research results, and (d) adaptation and development of methods and equipment for effective and economical farm and rural applications of electric energy, used as power, heat, light and other electromagnetic radiations for plant and animal production, farm processing and rural living.

The importance of Agricultural Engineering research to the nation's agriculture is shown by the fact that power, machines and structures with which it is concerned are essential facilities for every one of more than 3.7 million farms on which equipment and buildings valued at over 45 billion dollars are used to produce and handle about 600 million tons of crop and animal products each year. Also, the solutions of most plant and animal production problems are in part determined by the machines and structures available and likewise almost every new finding in soil, plant, or animal science research requires additional engineering research for its most effective implementation. As the relative cost of labor increases and the mechanization of agricultural operations progresses, engineering research becomes increasingly important. Since the close of World War II the annual man-hours of farm labor has been reduced about 37 percent, from 17.4 billion to 11.0 billion, the number of tractors has doubled, from about 2.5 million to nearly 5 million, and the percent of farms served by electric power lines has also doubled from about 48 to over 97. Each farm worker has available between 30 and 40 mechanical and electric horsepower. The investment per worker for land and other facilities, which is higher than for all manufacturing, averages over $22,000. For many commercial farms it is more than twice as great and for certain types of farms over large areas it is $100,000 or more.

The following examples are illustrative of research accomplishments for which the Agricultural Engineering Research Division (AERD) has had a major responsibility:

(1) Determining the effects of plow size and type on performance in different soil types and conditions; the effects of tire characteristics such as cord arrangement, tread design, rim width and diameter, and inflation pressure on the performance of traction tires on different soil types and field conditions; and the effects of methods of manufacture and steel specifications on the service of disks used on agricultural implements. The determinations are being used by the farm equipment industry and technical advisors to farmers as well as directly by farmers.

(2) Agricultural engineering research has made possible the effective ginning of the machine and rough hand-harvested seed cotton. The developments of this research program have been a primary factor in maintaining the competitive position of cotton.

(3) In cooperation with several State Experiment Stations, good progress has been made in mechanizing the harvesting and farm handling of several fruit crops, including cherries, blueberries, prunes, and dates. This is particularly true for tart cherries where labor requirements have been reduced by 75 percent and costs by 50 percent.

(4) Ventilation of livestock buildings--Research in cooperation with State Experiment Stations has obtained much needed basic data on the heat and moisture given off by cattle, hogs, and poultry, and on the influence of building environment on production and feed consumption. The heat and moisture dissipation data are considered basic design data for ventilation systems of poultry, dairy, and swine buildings. They appear in design handbooks including the 1962 Guide and Data Book of the American Society of Heating, Refrigeration, Ventilating, and Air Conditioning Engineers, and are used by makers of ventilating equipment, prefabricated buildings and package buildings as well as by specialists advising farmers on their own construction. Building improvements resulting from the above research have contributed to the substantial rise in efficiency of livestock production that has occurred during the past decade.

(5) Research on light traps for insects, pioneered by AERD, has developed this device as a very effective means for detection and estimation of insect infestation. This development has aided quarantine activities and the planning of chemical control operations. More than 700 electric traps are in use to determine emergence and migration of the pink bollworm moth in the Southeast and the European chafer in the Northeast and thus facilitate more efficient use of chemical controls. An additional 400-500 traps are used for detecting mosquito populations. An estimated 400-500 general purpose electric traps are in use to determine new infestations of economic insect pests. Special multipurpose traps are used at points of entry to detect foreign insects.

The first field scale test of light traps for insect control was initiated in a 113 square mile area in North Carolina in 1962. Here 366 traps of special design are used for catching tobacco hornworm moths. The results

of the first season were promising and indicated that hornworm moth populations in tobacco can be reduced by use of electric insect traps when installed at a density of 3 per square mile over an area at least 12 miles in diameter. The effect of the light traps was not the same for the two species. The highest estimated reduction was 89 percent for male tomato hornworm moths. From this level the estimate ranged to 55 percent for female tobacco hornworm moths. A similar degree of reduction was observed on eggs and first-instar hornworm larvae on tobacco plants. Additional data are needed before recommendations on use of light traps can be made.

However, in spite of the rapid and unprecedented progress in farm mechanization during recent years, many important field and farmstead operations are still not mechanized or are only inadequately mechanized. There are also many unsolved problems in the mechanical preparation and conditioning of farm products for farm storage and use, and for sale. There are many undeveloped opportunities for the more effective and extensive application of the different forms of electromagnetic energy and there is urgent need for the development of more effective and economic farm buildings for storing products, sheltering livestock, and farm family living.

In view of the rapid multiplication and widening distribution of nuclear weapons and the failure of all current efforts toward disarmament, plans for future agricultural engineering research may well give consideration to types of building construction that would afford protection from fallout for families, livestock and stored products in case of attack. Consideration might also be given to development of types of essential equipment, such as well pumps, that could be kept in operation in case of power failure.

Agricultural Engineering research is carried out by the Agricultural Engineering Research Division of the Agricultural Research Service of the U. S. Department of Agriculture, by nearly all of the State Experiment Stations, and by farm equipment manufacturers, manufacturers of building materials and prefabricated buildings, and to a limited extent by trade associations.

A characteristic of current Agricultural Engineering research is the relatively small program of the USDA and also of the State Experiment Stations compared to that of other "Units" of public research, to the agricultural engineering research by industry and to the volume of agricultural production. This imbalance is serious because 80 percent or more of all agricultural research involves engineering, either during its conduct or during the application of its positive findings. Also as agriculture becomes more complex the need for expanded public agency research in agricultural engineering to determine for industry the fundamental principles and the basic requirements of the power, machinery and structures needed for an efficient agriculture become increasingly urgent.

Thus, although there is need for the expansion of independent basic research in agricultural engineering, there is also need for a considerable expansion of agricultural engineering research cooperative and concurrent with other related agricultural research programs and also cooperative with industry whenever circumstances indicate the desirability of such cooperation. It should be noted that public agency research in agricultural engineering is complementary to and often cooperative with private research and not a competitive duplication of research by industry.

The Agricultural Engineering Research Division has 33 of its 146 professional workers located at the Beltsville Agricultural Research Center; 9 at 7 Federal field stations, and 104 at 31 State Experiment Stations.

Of the 104 Department professional workers now at State Station locations, 28 are in 7 specialized Federal laboratories, such as the National Tillage Machinery Laboratory at Auburn, Ala. Most are working cooperatively with State-employed workers on mutually agreed problems that have both State and National Significanace. Much of the research is carried on by teams including both engineers and scientists trained in other disciplines.

The program at Beltsville includes leadership for work done in the field and research on problems of National interest. Basic research involving 27 engineers conducted at 15 locations, including Beltsville, deals with soil and equipment relationships, pesticides and fertilizers application, crop conditioning, cotton ginning, environmental requirements (including light) for livestock, electromagnetic radiation for seed and plant product treatment, insect attraction and destruction, and nondestructive determination of fat and lean on live animals. Most of the work at other locations is directed toward solution of specific problems.

The program of the Agricultural Engineering Research Division is reported under 14 Research Areas shown in the Table of Contents.

AREA NO. 1: SOIL - MACHINE RELATIONSHIPS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle gear, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundamental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved crops response and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; Athens, Georgia; State College, Mississippi; and East Lansing, Michigan. USDA personnel working on this project are stationed at Auburn, Alabama, and Ames, Iowa. Much of the work at the laboratory at Auburn is with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests, and field observations.

The Federal scientific effort devoted to research in this area totals 7.3 professional man-years. Of this number 1.0 is devoted to traction and transport devices and soil reaction; 1.0 to the effect of tillage practices on plant growth; 1.2 to the measurement of soil physical properties; 1.5 to equipment mechanics; 0.5 to the effect of soil mechanics; 0.5 to methods of mathematical analysis; 1.0 to systems of equipment for conservation farming; and 0.6 for program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

An important development in this field of research was the dedication of new facilities at the National Tillage Machinery Laboratory at Auburn, Alabama on May 17, 1963. A new building for tillage research has 14,000 square feet of floor space, and provides two 20 X 200-foot soil bins that permit year-round operations. These two new bins will supplement the nine similar-sized outdoor soil bins which are being used in tillage research at Auburn. Also dedicated was a new laboratory-administration building, which houses three laboratories, service facilities, and offices. Scientists in two of the laboratories will study physical and mechanical properties of soils and how the physical condition of soil affects plant growth. In the third laboratory, model tillage tools will be tested. In dedicating this new building, Dr. Byron T. Shaw, Administrator of ARS said: "We hope, with the increased emphasis on the basic work here to find some of the answers to farmers' tillage problems, and to develop principles that can be used to help farmers fully utilize their equipment".

A. Traction and Transport Devices and Soil Reaction.

This project is designed to determine and evaluate the effects of various construction, material, and operational factors on the

performance of tires and tracks when used for traction and for transport.

1. A study designed to determine the effect of rim diameter on rear tractor tires showed that drawbar pull, coefficient of traction, and power efficiency all increased with increases in rim diameter. All tires had the same cross sectional area, lug design, were loaded with the same static load, and inflated to give the same deflection. Performance of all tires were compared in the same soil conditions and two soil types. Five 12.4" tires with rims varying from 24" to 42" were used. In Lloyd clay the tire on the 42" rim pulled as much at 16% slip as the tire on the 24" rim pulled at 26% slip and 25% more with both tires slipping 16%. The differences were approximately the same in a loam soil. Loading the tires to give them equal dynamic weight at 20% slip reduced the differences only slightly.

Another phase of this study was to test two tires having equal static load ratings but varying in both tire section and rim diameter to determine whether or not increasing tire width would compensate for the increase in rim diameter. Tires used were a 12-38 and 13-28 both inflated to 14 psi. At 16% slip the increase in drawbar pull for the 38" rim was 10% and 20% respectively in the clay and loam soil. This is near the differences found for the 12.4" tires having 38 and 28 inch rims respectively.

Cooperation with the ASAE Tractive and Transport Efficiency Committee was continued. Two programs are underway. Progress is being made on the development of a glossary of terms. The second program, recently organized, is designed to determine the effects of track shoe design on track performance. Preliminary work is underway on this study.

Two series of tests were made comparing conventional and low pressure tires as traction devices. Data for these tests are not completely summarized. Final reports will be prepared as quickly as possible.

Preliminary tests have been made cooperatively with a group representing companies manufacturing rear tractor tires in an attempt to develop a basis for giving tires a torque rating comparable to the static load rating now used. This work will be continued.

A program to determine the effects of lug stiffness on the performance of rear tractor tires was started. Tests data indicate that the first tires prepared for use in this study did not have needed variation.

The bar-table developed on this project and used in the studies of tractor tire tread movement was loaned to one of the tire companies. They report that it was an effective tool in helping to determine the effects of some tire designs on tire wear.

B. Effect of Tillage Practices on Plant Growth.

1. The study of basic factors applicable to the design and use of deep tillage implements was continued. The 18" vs. 6" depth of tillage plots were ripped 6" deep over the row only and planted to determine any carry-over effect of the deep tillage treatment. The yields of cotton were 1.36 bales/acre for deep tillage (18") and 1.31 bales/acre for the check treatment (6"). The yields of cotton on the 36" vs. 6" depth of tillage plots were 1.56, 1.44, and 1.41 bales/acre respectively for the 36" depth of tillage 36" fertilizer depth, 36" depth of tillage 6" fertilizer depth, and 6" depth of tillage 6" fertilizer depth. The rooting depth of the main taproots were 12.27", 11.40", and 8.35" respectively. A good stand was not obtained on the plots this year which partially accounts for the lower yields. After the 1963 season it is anticipated that these plots in the Lloyd clay loam will be discontinued and similar trench tillage plots will be established on Norfolk sandy loam.

C. Measurement of Soil Physical Properties.

1. This project covers the work on the relationship of soil physical conditions to design and use of tillage machinery. It includes basic laboratory studies, bin tests, and field tests.

Theoretical terms that have been used successfully in similitude studies of plane chisels in artificial soil were employed in similar studies with natural soil. Model data predicted prototype results satisfactorily but not as closely as they did in artificial soils. Cause of this deviation can be attributed to soil cones forming on the tools only in natural soil. The effect of these soil cones was to essentially alter the shape of the tool beyond that which was accounted for in the assumed pertinent variables.

Experimental work completed in a deeper spring and fall plowing study was initiated. Significant reductions in soil strength as measured by the penetrometer have been secured by deeper plowing which removed a traffic pan. Yield data did not reflect any difference due to method of tillage but moisture was not a limiting factor in this crop year. While there was a slightly greater cloddiness in the deep plowed plots, there was no reduction in cotton stands.

Tensile strength studies were continued with prepared briquettes made from the Laboratory soils. Strength-moisture loss relationships were continued on a limited basis and no new conclusions can be reached concerning this aspect of work.

This was the fourth year of a 5 to 7 year planned program to determine the effects of the crop preceding and the depth of a seedbed preparation on peanut production.

The entire area was plowed uniformly in 1962 and planted to the selected variety of crops that precede the 1963 peanut crop.

Wear resistance data of plastic materials was analyzed from laboratory tests of different size abrasive sand. The coarser sand particles caused a greater difference in wear resistance between polytetrafluoroethylene (Teflon) and polyethylene. A new commercial wear machine for plastics was tried but found to have less correlation with field experience than the National Tillage Machinery Laboratory wear machine. Field studies of wear resistance of plastics with farmers was continued which showed both Teflon and polyethylene economically feasible for use.

D. Equipment Mechanics.

1. The basic studies of disk design and operating parameters have been continued with full scale tools. The completion of a new dynamometer unit permitted a more accurate series of measurements. A disk angle control device was developed so that the angle about the vertical axis could be remotely controlled and its value recorded during operation. A series of studies was designed and measurements made to determine the influence of the disk angle on the forces which the soil applied to the disk during operation. The accuracy and completeness of the data was considerably better than that which was secured with the old apparatus. Continuous plots of disk angle vs. draft relationships were secured for five different soil conditions. Lateral and vertical soil forces on the disks were also measured as well as the moments associated with the three forces. Soil forces on the back side of the disk were greatest at low disk angles and in hard soil. The maximum net lateral force on the back of a 26 inch disk operating at a depth of 5" and taking a 6" width of cut was 360 pounds. This force was reduced to zero at approximately 40 degrees. The net force on the front of the disk then increased to 40 pounds at 50 degrees. Thus the technique of programming the angle of cut permits a rapid method of determining the angle at which the lateral forces are balanced on disks.

E. Effect of Soil Mechanics.

1. This research is designed to determine and evaluate the effects of various machine loads on the compaction of soil. Stress measurements and bulk density measurements made under single, dual and Terra (wide low profile) tires were made. Some attempts were made to improve prediction formulas but no significant improvement can be reported at this time.

F. Methods of Mathematical Analysis.

1. No new data were acquired during the past year. Further analysis of triaxial data reported last year indicates that one fact is clearly established. Soil compaction (volume strain) cannot be uniquely related to the magnitude of applied forces. Rather, compaction is related to the

magnitude of the forces and also the manner in which they are applied. The effect of manner, however, may be small enough so that in some circumstances it may be ignored since the most extreme manner of loading produced a difference of less than 10%. A thorough review of the mechanics of a continuous medium was undertaken in connection with a graduate course at Auburn University. Several possible mathematical strain descriptions were evaluated in an attempt to find suitable representation for large strains that often occur in soil.

G. Systems of Equipment for Conservation Farming.

1. The determination of requirements of tillage for corn was continued in Iowa with emphasis on the selection of suitable soil constants, methods of measurement and establishment of critical limits for both the row and interrow zones. Using the point quadrant technique and a self-recording automatic soil profile meter developed, changes in the porosity of the tilled soil layer and surface microrelief resulting from tillage operations were discernible among different tillage systems. Both total porosity and surface roughness are relevant to water management in the interrow area and are useful in evaluating tillage systems. A study was initiated to characterize changes in other properties of the plow layer attributable to tillage implements. Information of this nature will lead to the design and development of more effective and efficient tillage implements and systems.

A rotary sieve was constructed for measuring clod size distribution in soils. Investigations relative to the effect of aggregate size on their properties were continued, with emphasis on the moisture retention and transmission characteristics and organic matter distribution within aggregates. The volume of water retained per unit volume of aggregate decreased as aggregate size increased and was associated with changes in apparent density of the aggregate. In most soils studied the carbon and nitrogen content of aggregates was inversely related to aggregate size. Generally the carbon and nitrogen content of the surface of an aggregate were greater than that within the aggregate. Soil aggregates are discrete entities possessing moisture and organic matter characteristics that vary with size. Such information is useful in evaluating the row zone resulting from various tillage practices. Major corn yield differences due to tillage practice at 5 locations in Iowa were generally related to difference in stand.

Early spring applications of herbicides to control weeds made it possible to successfully grow corn following corn without tillage. Surface residues caused some difficulty in planter operation, but tilling a narrow band at a shallow depth greatly reduced this problem. Manipulating the soil with tillage tools may be unnecessary if weeds are controlled chemically and satisfactory stands are obtained. However, on some soils soil disturbance to break the surface crust may be desirable for soil and

water conservation. Yield results of continuous corn on contoured unplowed ridges showed that after 11 years high yields (100 bu./A.) were maintained with practically no erosion. Results of model studies on the use of "Teflon" on the surface of tillage tools showed that scouring was improved, draft was reduced 6 to 38 percent, and that "Teflon" or "Teflon" with glass filler would wear 8 to 10 times faster than steel.

H. Foreign Research Under Public Law 480 Funds

1. A 2-year research project was completed in May, 1963, under a contract under PL 480 funds by the State Research Institute of Agricultural Engineering, Helsinki, Finland. The research included studies of: characteristics of wheel-type farm tractors on steep slopes (such as cleared forest areas), gasoline and diesel engine performance at low temperatures, suitability of wheel-type farm tractors for forestry work, and the mechanization of forest tree seeding.

Tractors were tested on level ground and on 10 and 15° slopes in summer and winter, under various soil temperature, and moisture conditions, and wheel chains were developed for improving the pulling power of the tractor especially on slopes. Equipment used to improve the pulling power included: wheel weights, special "Vakola" wheel chains developed at the Station, half-tracks for use with the rear wheels, and dual wheels. On a meadow with 10° slope for example, the best drawbar pulls were obtained when the tractor was equipped with wheel weights, or when the tractor was equipped with both wheel weights and wheel chains. On a meadow with 15° slope, the best drawbar pull was obtained when the tractor was equipped with both half-tracks and wheel weights.

Winter tests were made on a level ice covered farm road cleared of snow, on a level road made by compacting the snow, and on an ice covered farm road cleared of snow with 10° slope. The best drawbar pulls on any of these winter roads were with the "Vakola" wheel chains designed at the Station, followed by the half-tracks, and then the snow chains. However, these chains, because of their spikes, are prohibited by law from public roads, and are not allowed on maintained winter roads at the large logging sites because the chains break the road surface. The Vakola wheel chains are considered suitable for work in the farm forest or small area.

Tests were made in Finland on a gasoline burning tractor engine to determine the effect of the following factors on the wear rate of the top piston ring: working temperature, oil viscosity, repeated cold starts, loading, engine speed, and additives. The wear tests on the piston rings were made by the use of radioactive isotopes. The top piston rings were irradiated in the Harwell pile in England, and were fitted to the engine by the use of long-handled tools. The radioactivity of the oil, measured after a certain period of time, furnished an indication of the wear of the piston rings. The results of the wear tests relating to the working temperature

of the engine showed that the wear rate was considerably higher at the lower temperatures, especially at starting, caused chiefly by lack of enough oil in the cylinders. The wear rate was lowest at 80° C (176°F). No significant effect on the wear rate was observed during the tests from the additives sprayed into the inlet manifold, or mixed with the fuel or with the oil. It is hoped that a report can be issued in English on the research conducted in Finland for use by our professional and technical workers that are interested in the performance of farm tractors in cold climates.

The suitability of wheel-type farm tractors for forestry work was investigated during two winters in Finland. Timber harvesting in that country is usually done in the wintertime. In large, state owned logging sites in North-Finland during the 1962-63 harvesting season, about 50 percent of the timber was transported by tractors, 10 percent by trucks, and 40 percent by horses.

Important factors when considering the suitability of farm tractors for this work included: travel speeds, drawbar performance, braking efficiency, and ability to maneuver in rough terrain. Travel speeds available (1 to 18 mph) were considered adequate except that 20 mph would be advantageous for idle travel on main haulage roads and highways. Drawbar horsepower for year-round timber transport should be somewhat more than on present common farm tractors - probably a wheel-type farm tractor weighing about 4 tons with a 70 to 80 hp engine would be more suitable to forest work. Braking efficiency of the tractor would have to be improved for taking timber out of the woods in hilly terrain. A ground clearance of about 2 feet would be necessary in the roadless terrain. Tractors used in timber transport should have power take-off provisions from the sides, front, and rear.

Tests were made of tillage implements in Finland for use in mechanizing ground preparation on steep slopes for the seeding and planting of trees. The condition desired for planting was about 650 "spots" per acre from which the raw humus was entirely removed without loosening the mineral soil, each spot about one square foot in area. Several of the implements tested made bare spots as they progressed up or down the slope, each spot usually varying from about one to three square feet in area, with average skips between spots of from 8 to 16 feet within the row, and with about 6.5 feet between rows of spots. A land clearing moldboard plow and a disk plow were also tested for comparison with the implements that made rows of spots cleared of humus.

Two wheel tractors were used for the tests which had been specially reinforced and shielded to prepare them for the severe service required. Each was also provided with a front bumper and ballast weighing about 550 lbs. A safety cab with a sheltering steel wire net was provided to protect the operator. Observations made during the tests included the time

for making a spot line, the length of spot line, thickness of humus, and the frequency, area, and depth of spots. The mean net work times per acre for all of the implements were: 1.14 hrs. on a steep stoneless slope, 1.31 hrs. on a steep slope with a thin layer of humus, 1.44 hrs. on a steep slope very stony, and 1.62 hrs. on a slightly inclined slope with a thick layer of humus.

2. A 4-year research project contract was executed December, 1961, under PL 480 funds with the Agricultural Research Station, Beit Dagan, Israel. The research conducted concerns tillage methods and implements for mountain farms. Field experiments have been conducted to study soil translocation, both qualitatively and quantitatively, as affected by tillage implements, tillage methods and slope.

The following treatments were examined:

a. Plowing with a moldboard plow along the contour turning the furrow downhill.
b. As above, but turning the furrow uphill.
c. Plowing with a disc plow along the contours, turning the furrow uphill.
d. Tillage along the contour with a cultivator and an orchard disc harrow.
e. Tillage perpendicular to the contour with a moldboard plow and a cultivator.

The treatments were applied on one or more of the following gradients: 17-19%; 13-15%; 10-12%; and 5-9%.

The area chosen for the experiment was typical of the soils of the hilly regions, combining all the above gradients. It was mapped and a plot of 12 x 35 m (39 x 115 ft.) was allotted to each treatment on each gradient. Implement performance was registered during tillage, together with tillage depth, tillage width, speed, and qualitative evaluation of the performance. The extent of soil translocation was measured after each tillage and expressed as the changes occurring on the profile at three cross-sections in each of the tilled plots. The surface of the ground was determined with a "profilograph" that was specially designed for this purpose.

The following conclusions may be drawn from the first year's investigations: uphill casting of the furrow with a moldboard plow, working on the contour, prevented extreme downhill movement of the soil in gradients up to 19%. Similar results were obtained with a disc plow, but the maximal gradient was limited to 13% in this case. Tillage with a cultivator did not cause any soil shift on the steepest slopes up to 19%. Similar results were obtained with an orchard disc harrow but with a maximum slope of 9%. Plowing with a moldboard plow perpendicular to the contour resulted

in a slight downhill soil movement. Performance of various tillage implements on slopes exceeding 15% will be studied further.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Traction and Transport Devices and Soil Reaction.

Vanden Berg, G. E. and Gill, W. R. 1962. Pressure Distribution Between a Smooth Tire and the Soil. Transactions of ASAE, Vol. 5, No. 2, pp. 105-107.

Forrest, P. J., Reed, I.F., and Constantakis, G. V. 1962. Tractive Characteristics of Radial-Ply Tires. Transactions of ASAE, Vol. 5, No. 2, pp. 108 and 115.

Reed, I. F. 1962. Effects of Inflation Pressure, Load Drawbar Pull on Axle Height and Rolling Radius of Six Tires. Transactions of ASAE, Vol. 5, No. 2, pp. 125 and 132.

Vanden Berg, G. E. and Reed, I. F. 1962. Tractive Performance of Radial-Ply and Conventional Tractor Tires. Transactions of ASAE, Vol. 5, No. 2, pp. 126-129 and 132.

Wann, W. L. and Reed, I. F. 1962. Studies of Tractor Tire Tread Movement. Transactions of ASAE, Vol. 5, No. 2, pp. 130-132.

Vanden Berg and Reed, I. F. 1962. Evaluating Performance of Traction Devices. Presented at National Farm Construction and Industrial Machinery Meeting of S.A.E., Milwaukee, Wis., Sept. 10 - 14.

AREA NO. 2: PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The planting geometry used on many crops is still the plant spacing which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the past have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

USDA PROGRAM

The Department has a continuing long-term program of applied engineering research on planting methods and means of applying fertilizer on various crops. Studies are in progress at 26 locations in 13 states (Arizona, Florida, Georgia, Indiana, Louisiana, Maryland, Michigan, Nevada, New Jersey, Oklahoma, Texas, Washington, and Wisconsin). Sixty-nine field experiments were conducted in cooperation with state experiment stations, other ARS divisions, and commercial research units, which involved studies

with 34 crops. Eighteen special machines were provided to put in seed and fertilizer placement experiments this season - machines either solely or collectively designed and constructed by the Investigation Unit. Five new machines or new principles of study of previously designed special machines were designed and constructed by staff research engineers.

The Federal scientific effort devoted to research in this area totals 9.9 professional man-years. Of this number 1.1 are devoted to fertilizer placement and distribution equipment; 0.2 to seed planting equipment; 0.3 to transplanting equipment; 2.7 to equipment for establishment of forages; 2.6 to cotton planting and fertilizing equipment; 0.4 to corn planting and fertilizing equipment; 0.4 to vegetable planting equipment; 2.0 to decontamination of agricultural land; and 0.7 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Fertilizer Placement and Distribution Equipment.

1. Forty-eight experiments on the establishment of field crops and vegetables were put in cooperatively with various State, Federal and commercial research units. Thirty-two experiments were handled out of the Beltsville Station, three by the Southeastern Station, and thirteen by the Southwestern Station. Some typical results of the cooperative field experiments are: A new technique of measuring or detecting action of fertilizer-seed placement was devised by this Investigation Unit the past season to complement field experiments with cooperating plant scientists. A special field machine was designed whereby the seed and fertilizer's action with the soil may be closely observed and tied in with unearthed seed-fertilizer position. This method employed high speed motion photography on a field testing device so that soil performance tests could be observed by an eight to one reduction of time (or speed - by slow-motion film). This study was made as a part of a planting-fertilizing study with small grains. In 1962, these field experiments on small grains were continued with Michigan and Indiana (winter wheat, spring oats) and separation of seed and fertilizer showed benefits on high rates of fertilizer application (up to 15 percent greater production). Several companies are advertising separate seed-fertilizer openers for drills, but many plant scientists feel the type of separation, if any, is not desirable for efficient use of the fertilizer. In a series of these tests on commercial seed-fertilizer openers with high speed photography only one of four openers tested in field performance trials gave separation of seed and fertilizer - and the placement of this one opener was not satisfactory in the opinion of the cooperating plant scientist.

From these trials, the most promising openers were studied in great detail, with the objective of designing an opener that would have good field performance. A successful 1 X 1 inch side placement opener with a seed firming wheel was made which, in turn, was used on seven experiments in 1962 with good performance; application for patent of the new opener was made;

and one company has made a new opener almost identical to this development and it has been sent to several State Agricultural Experiment Stations - in April, 1963. Other companies have discussed the trials reported at the National Meeting and apparently are planning on changes on their present openers.

B. Equipment for Establishment of Forages.

1. Twenty-one experiments on the establishment and production of pastures and haylands were put in cooperatively with State and Federal research units. Thirteen experiments were handled out of the Beltsville Station, three by the Southeastern Station, and five by the Southwestern Station. Some typical responses to the various studies are: In the rangeland of the Southwest excellent stands of three desirable forage species (switchgrass, sprangle top, and sideoats) were established in poor rangeland at one location with a special range mulcher-seeder machine in 1962. Seeding at another location was not successful. Considerable study and experimentation will be necessary to provide dependable methods and equipment, but this study shows promise of developing suitable equipment and practices for this problem. The successful establishment of a desirable legume in an established grass sod was repeated again in studies with the University of Maryland (trefoil-bluegrass). The use of a curved disk coulter displaced enough sod and gave suitable seedbed preparation for a grassland drill seed-fertilizer opener to firmly establish this legume. (It is difficult to get a good stand with this species in the mid-Atlantic area.) Further studies on management are following up this successful method of establishment. In a five-year study of the effect of nitrogen fertilization on forage production of an established stand of irrigated legume grass in the Northwest (ladino-orchardgrass - management studies) the greater production showed no profit the first two years. Two hundred pounds of N ($30) per acre were added - forage market price of $20/ton dry matter. However, on the third year, over $7 per acre was received as additional net return over no fertilization, $16 the fourth year, and $10 the fifth year.

C. Cotton Planting and Fertilizing Equipment.

1. Crop residue disposal by burying the residue in a vertical subsoiler slot was continued in Mississippi and California. Residual effects from vertical mulching in 1961 did not show up in 1962 in California. Subsoiling alone was as good as subsoiling and vertical mulching. Both were better than broadcast application of residue material. Results from Mississippi showed a slight but nonsignificant increase in cotton yield for vertical mulching on a Bosket fine sandy loam soil.

2. Precision tillage research first described last year was continued in California and also instituted in Mississippi and Texas. Precision tillage continued to give high yield increases in sandy loam soil in California but gave no significant increases in west Texas nor in Mississippi. The Mississippi plots were installed in the spring in moist conditions and this

may have contributed to the lack of response. Penetrometer readings in California showed that the effects of compaction and tillage persisted throughout the season. Yields were inversely proportional to the compaction of the soil as measured by a penetrometer. Seed cotton yields varied very little among six primary tillage methods in Mississippi in 1962. The well-pulverized condition of soil prepared by the disc harrow aided in germination and emergence, but the unbroken root zone prevented vigorous and productive plant growth and resulted in the lowest yield.

Precision tillage was employed in a minimum tillage system of cotton production in California. Four field operations from stalk disposal through planting were used in lieu of a normal sequence of seven operations used in the area. There was no significant difference in yields and horsepower requirements were reduced 70 percent.

Application of nematocides with the precision tillage equipment in California gave encouraging results. Although deep fumigation with the subsoiler increased yield 9 percent there was also a trend of increased yield from subsoiling and normal fumigation applied as a side dress operation. The combination of precision tillage and nematode control appears promising.

The relation of fertilizer placement and precision tillage was studied at several locations. Response from precision tillage was obtained in the coarse textured soils at two locations. Potassium was applied as a deep application with subsoiling and as a deep side dress application. Response to potassium seemed to be associated with precision tillage, indicating that the additional plant growth associated with deep tillage required more potassium. At Lubbock, Texas, the highest yields in major fertilizer element tests were obtained with a placement of four inches below and ten inches to the side of the seed furrow. Yield response to minor elements was small in these tests.

The influence of seedbed orientation on soil temperature at seed depth was studied at Lubbock, Texas. Beds were oriented north and south and east and west. For a twenty-five day period before planting the maximum temperature was 2° to 5° F. higher in the north-south beds. Further evaluation will be necessary before any statement could be made regarding the benefits to germination this higher temperature might have.

"Broadcast planting" of cotton was done at Lubbock, Texas, with a modified commercial planter on a flat prepared seedbed. The cotton was planted in rows 9 inches apart and a pre-emergence chemical was applied broadcast over the plot at the rate of one lb. per acre. The chemical was activated with a three inch application of water by sprinkler irrigation. Sixty-one pounds of seed per acre were planted and the resulting plant population was about 240,000 plants per acre. The cotton was grown without cultivation or hand hoeing and was harvested with a specially-designed stripper harvester. This cotton yielded approximately one-fourth bale per acre

more than the check in 40 inch rows. Plant characteristics of the broadcast cotton were desirable for machine stripping.

3. Studies of horsepower requirements for primary tillage for cotton were begun in Mississippi. Data was recorded showing that the horsepower hours per acre increases rapidly with the depth of penetration. Accumulation of this data should help farmers in choosing the most economical system of tillage. For example, these tests have shown that using a disc harrow twice to a depth of 4.7 inches requires the same horsepower hours as one plowing at a depth of 7 inches. Soil type also has a tremendous influence on power requirements. A 65 h.p. tractor was able to till heavy clay to a depth of only one inch with a 12-1/2 ft. rotary bedder. The same machine shredded corn stubble and prepared a seedbed eight inches deep in sandy loam soil with a 90 h.p. tractor.

4. A black petroleum mulch was sprayed on six and eight inch bands over the planted seed row at rates from 60 to 125 gallons per acre at Stoneville, Mississippi, and Lubbock, Texas. The purpose of the mulch was to increase soil temperature and possibly maintain moisture in the seed zone. Maximum soil temperature under the mulch was increased as much as 8° F., but the soil moisture retention was slight. On the average, cotton came up about two days earlier where the mulch was used and final stands were slightly better. There was no significant difference in yield.

D. Corn Planting and Fertilizing Equipment.

1. Fertilizer placement studies on corn in Georgia have been terminated after three years of trials. As found previously, the 1962 studies gave further proof that one operation corn growing is highly feasible. More profit can be made as the one operation of planting, fertilizing, and cultivating has the lowest cost of producing high yields of corn. Treatments indicate that fertilizer applied on a 2 X 2 basis (two inches below and two inches to side of seed) in a complete analysis at planting time will give higher yields than split applications of nitrogen. The application of a pre-emergence herbicide (Atrazine) can eliminate the need for cultivations or post-emergence herbicides.

E. Vegetable Planting and Fertilizing Equipment (including potatoes).

1. In irrigated potatoes in Arizona, heavy fertilizer (1000# 16-48/A) showed placement of continuous bands at four inches on each side, two inches below were superior to closer and wider placement. This is definitely different from the accepted placement on dry land potato culture of two inches on each side and slightly below seed piece.

During two seasons of field experiments with potatoes in Western Washington, with each nutrient of the three primary fertilizer elements used separately and in combination in both band and broadcast patterns, banding in all combinations was conclusively superior to broadcasting. However, when

heavy rate applications showed salt injury to the stand, broadcasting part of the nitrogen with the remainder of the fertilizer in bands gave the best results.

F. Decontamination of Agricultural Land.

1. The effectiveness of various common types of farm and industrial machinery for removing fallout from farmland has been determined from investigations made during the past four years. The percentage of removal to be expected with the various types of equipment is now known, however, other removal factors such as the disposal of the contaminated soil, are still a problem. During 1962 Tayland winter wheat was grown to maturity on two types of soil for use in fallout tests. After contamination the wheat was removed with a combine, the stubble-covered ground was pulverized with a disc, and was decontaminated with a flail forage harvester or a street vacuum sweeper. Due to a poor isotope in the fallout simulant the tests were not as accurate as previous ones; however, they were accurate enough to demonstrate that while pulverizing allowed greater removal, particularly from the heavy loam soil, the decontamination still was inadequate with suction-type equipment unless followed by a scraping operation.

In the fall of 1962 tests were run with cement slurries and commercial liquid mulch solutions on the surface soil to develop a means of localizing the fallout in inaccessible or hard to remove places to hold it in place until it becomes less radioactive. The commercial mulches were considered too expensive. Sand and cement mixed with the surface soil and sprinkled with water did not form a cohesive crust. A slurry of 3-parts sand to 1-part Portland cement and about 1-part water was found to be the most satisfactory. The slurry was applied with a modified lime spreader and allowed to set. Some of the thin crust was crushed with a disc harrow or a corrugated roller in order to make it easier to remove. Attempts were made to remove both the crushed and solid crust with a rotary broom street sweeper and a side delivery rake. The rake proved satisfactory on both the broken and unbroken crust on the sandy soil not covered with vegetation.

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Decontamination of Agricultural Land.

* James, P. E., and Wilkins, D. E. August, 1962. Fallout Removal from Farmland. Presented at North Atlantic Section ASAE Meeting, Morgantown, West Virginia. ASAE Paper No. NA 62-202.

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AREA NO. 3: CROP PEST CONTROL TECHNIQUES AND EQUIPMENT *

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment, be it a small chemical sprayer or a giant bulldozer. In many situations, effectiveness of the equipment necessary may be essential to the success of the method which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control, and it is time consuming and costly. It is believed that with sprayers and dusters now used often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provide sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the new Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio, on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa; St. Paul, Minnesota; Columbia, Missouri; and Stillwater, Oklahoma; and at Wooster, Ohio, where a

*Except electric, which is in Area 11.

small part of an engineer's time on spraying equipment applies specifically to weed control. Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington Stations, on low growing crops. Pest control equipment research for certain crops is conducted; for cotton at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; Lubbock, Texas; and (particularly for boll weevil control) at State College, Mississippi; for peanuts at Holland, Virginia; and for vegetable crops at Forest Grove, Oregon.

The Federal scientific effort devoted to research in this area totals 13.6 professional man-years per year. Of this number 1.3 is devoted to basic studies in aerosols and spray formations; 0.7 to soil fumigation; 2.8 to insect control in grain; 1.3 to weed control in corn and soybeans; 3.5 to pest control in cotton; 0.2 to pest control in peanuts; 0.9 to insect and disease control by ground equipment in vegetables and other low-growing crops; 0.6 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.0 to aerial spray equipment for forest insect control; and 1.2 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Studies in Aerosols and Spray Formation.

1. The objective of the research conducted at the Pioneering Research Laboratory on Physics of Fine Particles at Wooster, Ohio, is to obtain basic theoretical and experimental information as a contribution to fine particle physics which should ultimately result in improvement of efficiency and distribution characteristics of pesticide application. Theoretical work included the following: (a) development of a mathematical treatment, based upon conditional probability theory, for Brownian motion systems where particles are of non-uniform size; (b) how to represent initial distributions of soil fumigant mathematically in, and the solution of, some typical problems on the diffusion of fumigant in the soil; (c) the solution of a particular stochastic (statistics with a time parameter) differential equation; (d) a treatment of measurements and the mechanics of droplet impaction based on stochastic theory. Stochastic analysis of the distribution of aerosol deposits was also studied, as were theoretical models of turbulent diffusion in aerosol mechanics. Experimental work involved the development of an ultraviolet exposure unit for spectrographic study of fluorescent tracers for aerosol deposit measurements. Data for several tracers and other fluorescent materials have been obtained and are being analyzed. Special methods for spectrogram density recording were applied to study of the fluorescent spectra.

Studies of thermal and moisture diffusion in pastes of fine starch particles are being made in cooperation with the USDA Soft Wheat Quality Laboratory, Wooster, Ohio. Studies of digital computer methods for

solving water gravity-flow problems in soils were conducted in cooperation with the Ohio Station.

2. Fungicide sprays of copper were applied at ten-day intervals to seven vegetables (collards, eggplant, lima beans, peppers, tomatoes, cucumbers and potatoes). Spray volume, drop size, and formulation were the controlled variables. The vegetables were selected for their different leaf characters and growth form. Neither the initial nor weathered deposits of copper applied in sprays of different drop size appeared to differ from each other by a significant amount. As would be expected, pubescent foliage appeared to retain more copper initially as well as after weathering. The low-gallonage application rates gave the best fungicide retention, and a spreader-sticker apparently increased initial runoff thereby reducing the initial copper deposit. An addition of oil increased copper adhesion on all seven types of foliage.

Sugar beets sprayed on a similar schedule indicated a relation between copper adhesion on the foliage and the amount of viscosity of oil used. Increasing either of these two factors decreased the amount of weathering taking place between spray applications.

B. Soil Fumigation.

1. The study and development of methods and equipment for controlling crop pests by the application of chemicals to soil was conducted in Ohio. The crops treated included over a dozen kinds of vegetables, potatoes, and sugar beets. Sour cherry trees were treated, and sycamore and white pine trees were treated for use in reforestation or strip mine reclamation. Pest control was attempted on diseases including potato scab, onion smut, pythium (damping off) and verticillium wilt; weed control was attempted by treating the seeds of nut grass, purslane, ragweed and smartweed; insect control was attempted on miscellaneous soil inhabiting root feeders, wire worms, and grubs; and nematode control was attempted.

Rotary tiller equipment was used for applying non-volatile materials requiring thorough mixing into the soil either in rows or over all treatments. The field cultivator with injector blades was used for more volatile materials injected under pressure and for side dressing of rows of living plants. Specially prepared equipment attached to a planter was used to introduce insecticidal and fungicidal material into the seed zone of onions at planting time. It is desirable to introduce these materials near but not actually in contact with the seed. Excellent control of smut and maggots was obtained with some of the available pesticides using this equipment, with yield increases of as much as 40 percent over untreated plantings.

Equipment which places an impervious seal of polyethylene film over a soil treatment has been in use for some time. The use of emulsions of asphalt, wax, or latex is being investigated as a less expensive method

of surface sealing. Pressurized equipment for handling these viscous liquid seals has been used successfully. The nozzle producing the most satisfactory surface cover with these materials is a double flat spray type. Width of the sealed strip is controlled by vertical position of the nozzle. The axis of the two spray patterns are inclined from each other and to the soil surface so that one axis is inclined 18 degrees from vertical toward the direction of travel and the other is similarly inclined in the opposite direction. A more nearly complete and continuous coating of all soil particles is obtained by this application than from a pattern having a single vertical or inclined axis of approach to the soil surface.

C. Insect Control in Grain.

1. In investigations made in cooperation with the Iowa Station for the control of the European corn borer, the major emphasis of the chemical control program was to screen new insecticides, develop systemic insecticide control, study the effect of particle size and amounts of carriers in granular formulations, and to study the rate of loss of insecticide residue on corn plants. The results of these studies indicated that in addition to the presently recommended insecticides, Telodrin at 0.2 lb./acre, Diazinon at 2 lb./acre, Zectran at 1.5 lb./acre, and Bayer 44646 at 2.0 lb./acre also gave good control of first- and second-brood corn borer larvae. The effectiveness of Sevin was increased by the use of Lovo, a spreader-sticker. American Cyanamid CL47470 and CL47031 showed systemic activity against corn borer larvae. Ground corn cobs were as effective as attapulgus clay granules as carriers for insecticides for borer control. Telodrin residues from granular formulations could be detected 90 days after application and residues from spray applications were less persistent.

Studies were undertaken to determine the effect of commonly used spray mix densities, viscosities, and surface tensions on flow rates with nozzle sizes at different pressures and temperatures. Results show that increases in temperature decrease density, viscosity, and surface tension. These changes in the physical properties of spray mixes were not independent, and although the flow rate was changed with physical property changes additional work will be needed to clearly establish the relationship of spray mix physical properties and flow rate. Experimental sprayers and granule applicators were improved and calibrated for applications of insecticides. The distribution of granules on and around corn plants was given further study.

2. Investigations on new mechanical and/or physical methods for insect control on grain crops have been initiated at the Southern Grain Insects Research Laboratory, Tifton, Georgia. The initial efforts have been devoted primarily to control of the corn earworm. Most of this work is being done in cooperation with other personnel of the Southern Grain Insects Research Laboratory, Tifton, Georgia.

Several methods for controlling the corn earworm have been tried with varying degrees of success: (a) Clipping corn silks off at the tip of the husk at 24 hour intervals did not lessen the infestation of the ears by corn earworms. (b) Orientation of corn ears and foliage was tried in preliminary tests as an aid in applying insecticides. Small scale tests indicated 66 percent of the stalks could be orientated by planting all corn seed in the same direction. (c) Corn silks grow as much as one and one-half inches in 24 hours which continuously expose new silks to insect attack. A gelatinous substance might be used successfully for protecting these new silks from insect attack. Equipment is being developed for applying such a material to corn silks. (d) A method of applying insecticides by brushing or rolling the materials onto areas requiring protection was tried. A wool paint roller was used with little success. However, the use of this roller produced criteria for designing equipment.

3. Field work was begun in 1962 with spraying equipment in Georgia for evaluating factors such as: nozzle types, pressures, gallonage, nozzle incidence angle and number of nozzles per row. No positive conclusions can be drawn from the data obtained because of the limited work completed, however, several facts were indicated: (a) Flat type nozzles are superior to either hollow or solid cone nozzles in spraying for corn earworm control; (b) Two nozzles per row used in these tests is not adequate for effective insect control; (c) Pressures in excess of 100 psi. are seldom justified.

4. Studies were made in Georgia for available methods for evaluating insecticide coverage in sufficient quantities for visual evaluations. A total of 46 dyes were screened as potential indicators of spray coverage. The five following dyes gave best results: Rodomin B, methyl violet, crystal violet, methylene blue, and Rose Bengal. In the field work this year, Rose Bengal dye was used with good results at a one percent solution mixed into the insecticide.

D. Weed Control in Corn and Soybeans.

1. In investigations made in cooperation with the Iowa Station, results from several experiments showed that early spring applications of Atrazine and Simazine on fall plowed, spring plowed, and unplowed ground controlled weeds in corn throughout the season. 2,4-D at 4 lbs. of acid per acre gave good control up to planting time. Although yield and stand differences were not significant at the five percent level, the data showed a slight trend toward improved stands and yields where some tillage was performed prior to planting as compared to no tillage. A rotary tiller that worked a 12-inch strip two to four inches in front of the planter gave better results than a cultivator sweep in front of the planter or disking in front of the planter.

Continued studies in Iowa on comparisons of liquid and granular herbicide formulations applied at planting time in bands over the row and over the entire area showed that liquids were as effective as granules for most

herbicides. Atrazine and Simazine were the exceptions, and the results showed that weed control was more erratic with the granular formulations of these compounds. Strip applications were nearly as effective as broadcast; however, it was always necessary to cultivate at least once where chemicals were applied in strips, and only when the chemicals failed was it necessary to cultivate where overall applications were made.

Studies on mechanical cultivations in Iowa showed that harrowing after planting did little to improve stands, yields, or weed control. However, when the rotary hoe was used with 3 cultivations, harrowing after planting showed a slight improvement in weed control. Although three cultivations gave substantially better weed control than two cultivations, stand and yield data showed that two were as good as three. Two cultivations resulted in yields and stands that were as good as or better than various combinations of rotary hoeing and weeding with two and three cultivations. Shallow cultivations with rotary hoes, dragging hoes, and spring-tined weeders improved the weed control but not enough to materially affect yield.

The effect of varying the percentage formulation and rates of active ingredient of granular herbicides was studied in Iowa. All pre-emergence chemical treatments gave better weed control and higher yields than the untreated check. Ten and 20 percent Atrazine were equally effective. Ten and 20 percent formulations of 2,4-D at the 2 and 4 lb./acre rates were equally effective. The 4 lb./acre rate of 2,4-D did not improve weed control and showed no visual evidence of damage; however, yields were slightly lower than the 2 lb./acre rate. The Atrazine formulations gave better weed control than the other chemicals.

Spherical and regular granular formulations of 10 and 20 percent 2,4-D were applied in Iowa with John Deere, Gandy, and Noble boxes attached to an electrically driven cart that operated on a portable track. Distribution as indicated by photographs of granules caught on a plastic sheet showed little or no difference among machines. The number of granules per square inch varied considerably and there was no indication that patterns of spherical and regular granules were materially different. Spherical granular formulations of the 12/20 mesh size gave better weed control than equal amounts of 12/20 regular granules.

A number of commercially available or experimental herbicides were evaluated in Iowa for pre-emergence weed control in corn and soybeans. Atrazine, Randox and Randox T at recommended rates again resulted in best weed control in corn. Amiben and Randox gave the best results in soybeans. Directed post-emergence spray applications of Dowpon and 2,4-D combinations resulted in some crop damage but improved weed control. Similar treatments with Lorox showed promising results.

A study of sampling procedures for estimating yields of mature weed infestations was carried out in Iowa. Precision indices were calculated

for various sampling methods involving different fractions of the entire experimental plot. Loss of precision did not exceed 25 percent when as little as 40 percent of the plot was harvested in random segments. These techniques will permit efficient harvesting of mature weed infestations from herbicide tests and crop-weed ecology experiments.

Field studies were made in Missouri to determine the effect of row spacing on Clark soybean yields with and without pre-emergence treatments of Amiben at a rate of 3 lbs./acre. Abnormally high variability caused by uneven soil moisture conditions made the study very difficult to analyze. Because of this high variability there were no significant differences in yields of soybeans due to mechanical or chemical treatments.

Studies of the effect of three tillage methods on three weed control methods were conducted in Missouri for the fifth and last year. Corn yield was significantly lower in plots where the soil was prepared by conventional methods than plots where the soil was prepared by minimum tillage methods. There were no significant differences between any of the three weed control methods; (a) cultivate as needed, (b) pre-emergence 2,4-D and cultivate as needed, and (c) pre-emergence Atrazine. This indicates that the condition or smoothness of the soil surface has no effect on the action of the herbicides as determined under field conditions. The results indicate that a full season chemical weed control program is essential when using minimum tillage methods of soil preparation for corn production.

Field trials to determine the effect of rainfall (or irrigation) on weed control with granular and liquid formulations of 2,4-D were conducted in Missouri for the second year. Early applications of one and one-half inches of water immediately after pre-emergence application increased the weed yield significantly and caused the corn yield to be significantly less than the treatments where no water was applied. The pre-emergence applications of both liquid and dry formulations of 2,4-D suppressed the number of weeds. The corn yield was higher in plots receiving the granular formulation of 2,4-D.

Studies were made in Missouri to determine the effect of directed post-emergence applications of dalapon on corn. Four degrees of leaf protection were employed with two nozzle heights. The leaf protections used were (a) none, (b) leaves tied up, (c) shield leaf lifter, and (d) wire leaf lifter. A mechanical shield type leaf lifter was very effective in minimizing the dalapon damage to corn. Wire type leaf lifters will have to be improved before they can be recommended for this application. Even when maximum protection was used by tying the leaves, there were visual damage to the corn plant, but this did not reduce the yield significantly. With the 3-pound rate of dalapon there was no apparent corn yield reduction when adequate leaf protection was provided.

A special long-boom sprayer was designed and constructed in cooperation with Crops Research Division, Southern Great Plains Field Station, Woodward, Oklahoma. The sprayer was constructed by using the chassis of a used self-propelled combine. A 100 foot boom is supported by a moveable frame in front of the combine. The spray tank was mounted in the center of the combine chassis. Modifications to the combine chassis included (1) moving the engine down and to the rear of the combine, (2) replacing the tires with Air Force B-50 bomber tires, and (3) increasing the tread width to about 10 feet. The sprayer can easily spray an acre per minute and is designed for use in open range areas too small for aerial applications.

A study was made in Missouri to determine the minimum mixing rates for applying several dry-formulation herbicides. A special spray stand was constructed to evaluate the performance of standard sprayer components when applying herbicides at different concentrations. The results of this study indicate that the following herbicides and minimum volumes of application are required for satisfactory sprayer performance when using a jet hydraulic agitator in a 55 gallon tank; Propazine 8 gallons per acre, Atrazine 12 GPA, NaPcP 15 GPA, Simazine 18 GPA and Linuron 20 GPA.

E. Pest Control Equipment for Cotton.

1. Studies on mechanical methods of destroying fallen cotton squares were conducted in cooperation with the Entomology Research Division of ARS at the Boll Weevil Research Laboratory, State College, Mississippi. A flail type forage harvester was modified for preliminary testing. The modifications included the addition of baffles to concentrate the air movement into the flail at ground level. Tests indicated that 90 to 98 percent of the squares that could be covered with the flail unit could be picked up and chopped. This yielded a boll weevil population reduction of from 90 to 93 percent. An experimental row crop flail type machine was developed for entomological testing during the growing season of 1963. Preliminary tests have been conducted on this machine which indicate that from 76 to 94 percent of squares distributed on row profiles can be removed, depending on ground and flail speeds.

2. Work on soil incorporation of herbicides was continued in California. This work is needed because most pre-emergence herbicides for use in cotton require moisture for activation. Soil incorporation of herbicides provide more moisture than surface application under dry conditions. Three rotary cultivator designs were evaluated further this year for their efficiency in mixing herbicides with soil, and for their power consumption. Two experimental rotors, one with knife blades and one with angle iron blades proved to give better mixing of the herbicide and soil. The knife type required considerably less power in both sandy loam and clay soil. Granules were easier to mix uniformly with the top two inches of soil compared to liquid sprays. The rotor alone did not hinder cotton emergence, but when it was followed by a packing roller the emergence was decreased

to unacceptable levels. Acceptable weed control with several herbicides was obtained at rates that did not damage the stand of cotton.

In Mississippi a combination underground herbicide applicator and planter was designed, constructed and evaluated. Early results of a new concept, the triband method of weed control, looked very promising. This concept consists of placing a highly active, lowly selective, herbicide in bands on each side of the crop row and using more selective post-emergence sprays for controlling weeds in the drill row. Important features of this development include (a) precision placement of the chemical in bands (b) ease of planter adjustment and good control of planting depth, and (c) a finished bed adequate for post emergence operations without extra rolling. Field experiments indicated that cotton has the necessary tolerance for subsurface triband treatments with the experimental chemical EPTC. One of the most encouraging aspects of these early results has been the effective control of nutsedge in highly infested fields.

Soil incorporation of fungicides with rotary cultivators was also studied in California. The rotors were reduced in width from eight inches to four inches for these tests. Fungicides in granular form were more effective than sprays, and soil incorporation did not improve their effectiveness. Best results were obtained with the in-furrow application of granules.

3. Granule metering and distribution studies of three makes of applicators with two designs of rotor bar metering devices and two types of nozzles showed no distinct advantages of either metering mechanism or nozzle type in Alabama. Depth of material in the hopper or rotor speed did not materially affect discharge rate. Cross winds greater than 10 mph caused severe distortion and shifting of nozzle patterns. A slight deviation in height adjustment and mounting angle made little difference in distribution patterns of either nozzle type. In field weed control studies with two different chemicals on two soil types, the liquid-treated plots requires 9.3 man-hours of hoe labor per acre as compared to 11.2 man-hours for the granule-treated plots and 18.7 man-hours for the untreated check.

In a time-of-chemical lay-by test at two locations in Alabama, cotton laid by and treated with a chemical two weeks before normal lay-by time was free of weeds at harvest time. This early treatment saved from one to two cultivations and did not affect yield.

A study of the effect of the abrasive action of spray mixtures on spray nozzle tips was conducted in Alabama and Mississippi using fan nozzles and Diuron wettable powder. The percent increase in discharge capacity after 60 hours was significantly more for the brass (5.82 percent), and the curve for aluminum appeared to smooth out after 60 hours of wear, but it was impossible to determine any relationship of abrasive wear to changes in the pattern characteristics. Unless frequent re-calibrations are made to offset the wear of brass nozzles, an increased rate and subsequent cost of herbicide applied per acre can be expected. Use of the more expensive

stainless, hardened stainless steel, and chrome plated brass nozzles may be justified over the use of brass nozzles, depending upon the size of nozzle, the number of acres to be sprayed, and the concentration of the herbicide mixture.

Hand hoeing was eliminated in 40 inch row cotton by the use of a post emergence spray of Diuron plus a surfactant at Lubbock, Texas. Weeds were controlled from time of planting until July 9 with a rolling cultivator. On July 9, when the cotton was 10 inches tall, .2 lb. of Diuron and one pint of surfactant in 20 gallons of water was applied for post emergence weed control. This concentration was used per sprayed acre both for the band application and for the broadcast lay-by operation. The directed spray was applied by equipment developed in Mississippi by this project. The cost of the chemicals per acre was no more than the cost of hand hoeing the check plots, and although weed control is not a serious problem in the High Plains, the use of chemicals is becoming more attractive in this area as the labor supply dwindles.

Development of a parallel action wheel type chemical applicator for the application of several types of post emergence herbicides in cotton was continued. Overall performance of the applicator in laboratory and field experiments was excellent, and several commercial manufacturers are building this equipment. Displacement of spray pattern by a cross wind of 7 mph produced no significant adverse effects. An analysis of spray pattern and primary evaluation data indicated that a combination setting of four nozzles per row (two directed across the row and two directed parallel with the row and in reverse of direction of travel) will produce safe deposits and more effective control of weeds than two nozzles directed laterally across the row (using herbicidal naphtha in young cotton). Directed band and broadcast sprays of several herbicides in water indicated the wheel type applicator was highly adaptable in relation to various spray placements under several conditions of row profile and low hanging crop foliage.

New flame cultivation equipment was developed in Mississippi to minimize cotton plant damage from parallel, conventional (cross), and middle flaming. The newly designed conventional flame cultivator was relatively simple to set and performed well with respect to the degree of precision flame placement. Cotton plant damage from early parallel and conventional flaming with this cultivator was less severe than it had been in previous years, while the control of weeds was satisfactory. The performance of newly developed hooded burners for controlling weeds in middles far excelled that of any commercially available middle flaming device with respect to cost of fuel and control of the flame.

Preliminary evaluations of a locally-promoted electrostatic aerial sprayer were made. There was no evidence from a dye test to show any advantage from the charging mechanism. The spray dispersal unit appears to have considerable merit. From visual observation a very uniform breakup of the

liquid into droplets is obtained. It is felt that any further study of this device should begin in a laboratory under controlled conditions. Any concerted effort on aerial application is beyond the present scope and facilities of this project.

F. Pest Control Equipment for Peanuts.

1. Weed control in peanut production was accomplished in Virginia without the use of hoeing labor by using DNBP (alkanolamine salt of four to six dinitro-ortho-secondary-bulylphenol). This herbicide applied on a non-rolled drill surface was as effective as on a rolled surface at either nine pounds (active ingredients) per acre at time of planting or six pounds per acre at emergence. The six pound per acre rate at emergence was as effective for weed control as the nine pound per acre rate at planting. By using split applications of either six or nine pounds per acre at emergence and the same amount applied two weeks after emergence, no hoeing was necessary. When DNBP was used as a pre-emergence or emergence application only, the weed infestation in the drill was reduced to approximately 1500 to 3000 weeds per acre, requiring five to seven man-hours of hoeing labor per acre. The check plots, with no herbicide, had 9,800 to 11,200 weeds per acre and required 10 to 11 man-hours of hoeing labor per acre. Maximum weed control was obtained by the use of DNBP at the rate of nine pounds per acre at emergence and nine pounds per acre two weeks after emergence. The yields of peanuts receiving herbicide applications appeared to be higher than those not receiving herbicide, however, the differences were not statistically significant. This work is being terminated and the several years results will be published.

G. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops.

1. Research activities with ground equipment in Oregon consisted primarily of modifications to the U.S.D.A. row crop sprayer, making a series of applications for flea beetle and aphid control, and conducting spray penetration tests on broccoli with two general purpose air blast sprayers. Improvements were made to the row crop sprayer which consisted of changing the shut-off valves and plumbing lines and modifying the bracket for adjusting the top spray nozzles.

Spray penetration tests were conducted with a Mitchell general purpose air blast sprayer manufactured by Mitchell, Lewis & Staver, Portland, Oregon, having two 16-inch fans connected in tandem. The two fan shaped outlets showed air discharge rates of 1487 and 1591 cu. ft. per min., respectively, and a variation of air velocity within the outlet which varied between 5000 and 9700 ft. per min. This discharge rate is low and limits the maximum swath attainable. In one test using a 45-foot plot treated from two sides, the four middle rows did not receive measurable amounts of spray on the bottom leaf surface on one row side of the plant. The top sides of the sampled leaves of all 15 rows received deposit with

rates in excess of two and one-half gallons per acre. The data also show that light winds often prevent spray being carried to and being deposited on some leaf surfaces more than 12 feet from the machine on the windward side.

An airblast orchard sprayer manufactured by the Rear Manufacturing Company, Eugene, Oregon, was tested to determine amount of leaf coverage obtained when using a 78-foot plot width and making applications from two sides of the plot. Two leaves per plant and one plant per row were sampled in each of the 27 rows of broccoli. Each leaf sampled had two top and two bottom sampling areas. The data show that 29 percent of the top leaf areas had deposit rates greater than 30 gallons per acre and no rate less than one and one-half gallons per acre. On the underleaf surfaces, only 13 percent of the sample areas received sprays at rates in excess of 30 gallons per acre and only three areas with rates less than one GPA. The Rear and Mitchell machines were not designed for field crop spraying and would need modifications in the outlet to adopt it for this use.

A series of insecticide applications for the control of flea beetles and aphids was made with the U.S.D.A. Row Crop sprayer in cooperation with the Oregon Station. Five insecticide foliage sprays and two fungicide sprays were applied to replicated plots which were .63 acres in size. The timing of the applications was based on insect counts and extended from July to September, inclusive. Three insecticides were used, namely, DDT at two pounds per acre, Sevin and Thidan at one pound per acre of toxicant. DDT and Sevin were superior to Thidan in holding adults to about two beetles per ten sweeps. Thiodan was outstanding for aphid control.

Studies on control of Cercospora leaf spot on sugar beets with sprays were conducted in cooperation with the Ohio Station. Comparative experiments were conducted using different fungicide formulations, timing of applications and number of applications made with boom and nozzle hydraulic sprayer. The use of oil with fixed copper fungicide and an emulsifying agent improved effectiveness in disease control but not as definitive as the previous year. Data obtained in 1961 indicated that a combination of fixed-copper fungicide and an emulsifiable spray oil was capable of good control of Cercospora leaf spot of sugar beets when sprays are applied at six 10-day intervals, beginning about July 20 and ending about September 10. However, most growers were interested in reducing the number of applications by lenghthening the interval to 15 days. The use of oil with an emulsifying agent in 1962 improved the adhesion of copper fungicides so that there was no significant difference in disease control between 9, 12 and 15 day intervals of application. Maneb was more effective in disease control than copper.

Field experiments involving gallonage per acre, and pressure variations in spraying with an air-blast sprayer were made on sugar beets in northwestern Ohio. Six spray applications were made at 10-day intervals from July 21 to September 10 with a turntable type air sprayer with approximately 31,000 cu. ft. per min. The gallonage per acre was varied from 40 to 20 to

10 gallons per acre with pressure varied from 300 to 60 pounds per square inch. All application rates and pressures with the air-blast sprayer gave more effective control of disease than hydraulic spray applications at 160 gallons per acre.

Two sprayers for the application of sprays to grapes were compared, using a DDT spray. A "fixed spar" sprayer deposited a DDT residue of 3.4 parts per million, while an "overhung boom" sprayer deposited a DDT residue of 3.6 p.p.m. under identical conditions in the same orchard. The difference in residue deposit could not be considered significant.

An air-blast sprayer was used to apply methoxychlor to grapes, using three different air speeds indicated by fan speeds of 1,914, 2,807 and 3,700 r.p.m. Identical average residue deposits were obtained at fan speeds of 1,914 and 2,807 r.p.m. Increasing the fan speed to 3,700 r.p.m. increased the average residue deposit from 2.4 to 2.8 p.p.m. of methoxychlor.

H. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. Project activities with aircraft in Oregon during 1962 were primarily confined to installing a 250 horsepower engine in the Rawdon T-1 airplane; completing assembly of the aircraft, designing, fabricating and testing a streamlined dry materials distributor; and working on overhaul of a Bell 47D-1 helicopter which was received on surplus. Fixed wing aircraft were used to conduct spray pattern tests, granular pattern studies, spray penetration test on pole beans, and a series of experimental applications of a granular insecticide to field plots of red clover.

Spray deposit pattern tests were conducted in Oregon with two low-wing monoplanes, namely, a Rawdon T-1 and a Piper PA-25 "Pawnee". Both aircraft were powered with 150 horsepower engines. These tests showed that a symmetrical nozzle arrangement produced as uniform a deposit pattern across the treated swath as a non-symmetrical arrangement. Pattern tests conducted in 1962 after the Rawdon aircraft was equipped with a 250 horsepower engine and larger propeller, showed that the larger engine and propeller did not materially change the overall distribution of the deposited spray over that obtained with the smaller power unit.

Early in 1962, a distributor for granular materials which was developed on the project in Oregon, was mounted beneath the Rawdon airplane. This distributor was provided with endless belts to convey the dry materials to points of release. Performance tests, including deposit pattern studies, were conducted to determine points of release when all outlets were contributing. These performance tests showed that it was necessary to keep the outlets covered except during the application run. An effective 38-foot swath was obtained, however, at higher discharge rates, the outlets tended to clog when the depth of a granular material was near the design maximum and fingers or rakes were used to remove the material from the belt.

The distributor was modified to release the material from the top instead of from the bottom of the unit. This was accomplished by installing dual purpose gates in the top of the distributor, i.e., when gates are closed they prevent the material carried on the belt from sucking out and when open, act as adjustable scoops which remove a predetermined quantity at each location and release it over the top of the distributor. Evaluation tests of this method and position of release will be conducted in 1963.

Applications of a granular insecticide were made to five fields of red clover. These experimental applications were made to develop a safe and effective method of control for the lesser clover leaf weevil, the clover root curculio and the clover root borer. Control evaluations will be made in 1963.

Two airplanes owned and operated by commercial applicators were tested in cooperation with the Ohio Station for applying fungicide sprays to sugar beets to control Cercospora leaf spot. One plane was a Piper "Pawnee" with conventional boom and nozzle equipment. The other was a Piper "PA 18" fitted with two "Micronair" spraying units. Spray was applied at two rates, five and ten gallons per acre with both airplanes. Deposit pattern determinations were made with both aircraft using the copper fungicide spray formulation applied. The boom and nozzle unit gave the most uniform application but the "Micronair" equipment gave more uniform atomization. The performance of the two planes was very similar in terms of disease control at both gallonage applications used. The 10 gallon per acre rate was more effective than five gallons per acre rate with both units. However, the disease control was relatively ineffective compared to the hydraulic and air-blast ground equipment. Maneb fungicide spray gave better control than the copper sprays in this test.

I. Aerial Spray Equipment for Forest Insect Control.

1. Investigations were conducted at Beltsville, Maryland, in the development of aerial spray equipment and operational procedures for more effective control of forest insects. The degree of spray atomization is an important factor affecting the distribution and coverage of aerial sprays and therefore has a direct influence on their effectiveness for forest insect control. The effects of the following factors on atomization were studied: speed of plane; type, size and direction of nozzle orifices in relation to thrust line of the plane; spray pressure; and location of nozzles along the boom. The most important factors were air speed and orifice direction.

With a large nozzle commonly used on large planes for forest spraying increasing the air speed two and one-half times, from 80 to 200 mph, decreased the mmd (mass median diameter) of the spray 60 percent With the nozzle orifice directed to the rear and down 45° to the thrust line of the plane the decrease was from 324 $\pm$ 11 microns mmd at 80 mph to 127 $\pm$ 10 at 200 mph. With the orifice forward and down 45° the decrease was from 232 $\pm$ 11 microns at 80 mph to 93 $\pm$ 3 at 200 mph.

Finest atomization resulted when nozzle orifices were directed forward and down 20° to 45° in relation to the thrust line of the plane. Atomization was coarsest when they were directed straight to the rear. With a large capacity nozzle (7.4 gpm) at 170 mph air speed it ranged from 112 ± 5 microns mmd when in the forward direction to 187 ± 12 when directed to the rear -- an increase of 67 percent. With a low capacity nozzle (0.8 gpm) also at 170 mph, the range was from 84 ± 3 microns when in the forward direction to 166 ± 8 when turned to the rear, -- an increase of about 100 percent.

Somewhat similar percentage increases were obtained with both hollow cone and flat spray nozzles commonly used on Stearman and similar speed (80 mph) aircraft. With hollow cone nozzles the mmd was increased 55 percent when the nozzles were changed from a direction forward and down 45° to a direction straight to the rear. With flat spray nozzles the increase in mmd was about 95 percent when they were changed from the forward to the rearward direction.

The orifice type and size studies included solid stream (two sizes of check valves without nozzles), flat spray nozzles U50120 and T8010, and a large flooding type or flat sheet nozzle, K60. All were used at 170 mph with the orifice directed down 90° to the thrust line of the plane. The mmd ranged from 140 ± 4 from the largest nozzle (9.6 gpm) to 101 ± 5 with the smallest (.8 gpm).

These studies provide information for spray operators which will enable them to select the proper combination of nozzle, air speed, and nozzle direction to produce the degree of spray atomization desired in forest insect control operations.

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AREA 4, CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting and farm handling crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, only recently initiated, has already resulted in sizeable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research was initiated at Lake Alfred, Florida; and Davis, California; in cooperation with the respective State Experiment Stations. Equipment for cotton harvesting is under study at State College and Stoneville, Mississippi; Auburn, Alabama; Lubbock, Texas; and Shafter, California; in cooperation with USDA Cotton Ginning Laboratories and the respective Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Development of new techniques for harvesting forage is underway at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Georgia Experiment Station. Research on forage seed harvesting is underway at Corvallis, Oregon; and Clemson, South Carolina; in cooperation with the State Experiment Stations, farmers, and industry. Grain harvesting research is underway at Ames, Iowa; and Experiment, Georgia; in cooperation with the State Experiment Stations. Long fiber crops harvesting research at Belle Glade, Florida, is cooperative with the Everglades State Branch Experiment Station. Research on oilseeds and peanut harvesting

equipment and methods is cooperative with the Experiment Stations at Stillwater, Oklahoma (castor beans); Bogalusa, Louisiana (tung nut); and Holland, Virginia (peanuts). Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota. Equipment and methods for harvesting sugarcane are under study at Houma, Louisiana, in cooperation with the American Sugar Cane League. Tobacco harvesting research is conducted cooperatively with the Experiment Station at Lexington, Kentucky.

A contract with the University of Sao Paulo, Brazil, provides for investigations in mechanization of sugarcane production. Its duration is for five years and involves P. L. 480 funds with approximately $49,000 equivalent in Brazilian cruzeiros.

The Federal engineering effort devoted to research in this area totals 30.5 professional man-years. Of this number 4.0 is devoted to citrus; 5.4 to cotton; 5.5 to deciduous fruit; 1.5 to forage; 2.2 to forage seed; 1.3 to grain; 1.7 to long fiber crops; 3.4 to oilseeds and peanuts; 2.0 to potatoes; 1.0 to sugarcane; 2.0 to tobacco and 0.5 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. CITRUS HARVESTING EQUIPMENT

1. Harvesting Citrus. Over $50,000,000 are paid to workers who pick the crop by hand. Increased citrus production together with a shortage of suitable labor has created a need for improved methods and equipment for harvesting citrus fruit. AERD initiated research in cooperation with the University of Florida and the Florida Citrus Commission on October 1, 1962, at Lake Alfred, Florida, and in cooperation with the University of California, January 1, 1963, at Davis, California. In Florida fruit removal tests were conducted with a six-inch stroke inertia tree shaker, in the same plots of early season oranges in which the four-inch stroke shaker was used last season. The severe freeze of December 13 prevented any further fruit removal study this season. A fruit catching frame and frame-mounted inertia shaker were built and tested under various grove conditions. The catching-frame is equipped with conveyor and elevator to handle fruit in 10-box metal baskets. A picking platform mounting three pickers and employing the pick-and-drop principle (made by Mr. Boyer, Tampa, Florida) was tested in sparce fruit and half-dead Valencia trees. Pickers averaged only 17 boxes per hour compared to 20 boxes per hour by conventional picking with ladders.

In California one phase of the project objectives are to determine characteristic physical properties of the tree and its fruit and to utilize these properties to mechanically harvest the fruit. Preliminary tests performed on navel oranges indicate the following: (1) More than 75 percent of fruits detached with a pull applied in line with the stem were removed without stem

or calyx, and (2) fruits detached by spinning were removed with or without stem and calyx depending on the orientation of the spin axis with the fruit core axis. Limited studies of the electrical and thermal properties of the tree components and fruit indicate no apparent application of these properties to mechanical harvesting.

B. COTTON HARVESTING EQUIPMENT

1. In California cotton was machine picked with treatments for defoliation, desiccation, and no defoliation. Yield was reduced by defoliation. The yield of the desiccated plots was lower than the check but not significantly. The plant loss for the non-defoliated check was one percent greater than defoliated or desiccated cotton. No significant differences in ground loss or picking efficiency were detected but there appeared to be a trend for lower picking efficiency in the undefoliated cotton. In Mississippi the topping of rank growing cotton on July 11 and July 31 with a mechanical topper, and trimming lateral branches to allow increased air flow near the ground, produced the following results: (1) None of the topping or vertical pruning treatments affected total yield, picker performance, or foreign matter content of the harvested seed cotton; (2) late topping (July 31) and vertical pruning significantly improved classer's grade, but increased preharvest loss, and early topping (July 11) tended to decrease preharvest loss; and (3) the effect of topping and trimming on plant lodging was not measured because due to the dry season there was no lodging problems.

Late season weeds often reduce the grade of machine harvested cotton. In Mississippi this year a lay-by chemical was compared with no late season weed control in evaluating the effects of late season weeds on harvesting efficiency and cotton quality. Seed cotton harvested from the untreated plots contained four times as much grass as the treated plots; however, the lint foreign matter contents were about the same after two lint cleaners reduced the foreign matter from 5.4 to 2.1 percent in the untreated plots. Harvesting efficiency was not affected by late season weeds in this test.

A comparison of the spinning quality of cotton harvested by three types of spindle pickers and by hand was continued in California for the second year. Seed cotton and lint moisture content in the wagon was about two percent higher for machine-picked cotton than hand-picked, but there was no difference in lint moisture after ginning. The picking efficiency of the straight-spindled machines was greater than the tapered-spindle machine. Since fiber and spinning tests were inconclusive, this test will be continued another year before a complete report is given.

2. Several of the best methods of bottom picking determined by the last year's tests were used on a one-row picker this year in Mississippi. Because of rapid opening immediately after the bottom defoliant was applied bottom picking gave little or no yield on grade advantage in 1962. Green boll damage was light with all methods. About 60 percent of total yield was harvested when using the bottom picking attachments and about 90 percent when using regular picking equipment.

Several picker modifications were evaluated. Picking efficiency was increased about five percent when aggressive spindles, contoured compressor plates, and low boll pickup attachments were used on one side of a two-row picker. There was no further increase when aluminum ribs were installed in the contoured plates. "Ret-bar" pressure plates increased the picking efficiency about two percent over regular plates. There was no increase in picking efficiency when using an automatic height control device. The "cotton saver" shields were again helpful in cotton with rank stalks and long limbs, but they need to be modified to float with the ground contour or they will be bent. One-row cotton pickers modified for plot work proved a valuable research tool for the entire cotton research team. Methods of protecting the cotton picker between seasons were investigated and a system involving the use of a rust arrestor was recommended.

Picker head starting torque measurements were made with strain gauge torquemeters using eight greases in tapered spindle picker bars to establish the cause of high starting torque problems in cold weather. Test temperatures were 25°, 45°, and 65° F. with each of the eight greases. Some greases required as much as 28 h.p. to start in the coldest weather while others required half this amount.

Studies of oil and grease contamination of mechanically picked seed cotton were continued in Mississippi. The amount of grease contamination ranged up to 0.92 percent by weight of lint picked with a tapered-spindle type picker immediately after servicing. After one hour of operation the contamination was only 0.2 percent or less. In tests with pickers using lubricating oil for spindle gear lubrication the oil contamination of the cotton fiber was negligible and there were no adverse effects on fiber quality and spinning performance. In laboratory tests oil in measured amounts was sprayed on 16 pound lots of undried hand-picked and machine-picked cotton. Lint color appeared slightly affected by either the oil or mechanical picking, but other quality factors were not affected; except that there was a trend toward higher mill picker and card waste and a decrease in yarn strength with increased oil content.

The harvest conditions were good for the use of gleaning machines in the Mid-South this year. Harvesting losses were as great as one-fourth to one-half bale per acre in some fields due to heavy rainstorms. The recovery machines picked up an average of one bale from 10 acres and the lint was worth 22 cents per pound in average conditions. A new machine using carding belts picked up large amounts of dirt and trash.

3. Studies of methods of reducing moisture during mechanical picking and the resulting quality reductions were continued in Mississippi. Tests showed that (1) application of a fungicide to the spindle moistening system of a mechanical picker had no appreciable effect on seed cotton quality under the almost ideal harvest conditions this year; (2) spinning performance was not improved by applying the water-soluble bleach 2BS to the picker spindles as was the case in 1960 and 1961; (3) in comparing six different textile

conditioning oils with water as spindle moisteners, the oils had little effect on spinning performance but tended to adversely affect lint color, mill waste, neps, yarn break factor and strength; and (4) hexadecyl alcohol used as a spindle moistener in lieu of water enhanced the removal of trash in seed cotton but had no affect on classer's grade. In California, studies of moisture increase of seed cotton resulting from water used in the spindle picker were continued. The ratio of transfer of moisture from spindles to cotton was fairly uniform at 42 percent this year. The addition of wetting agents to the water had little effect on the ratio of transfer. Harvester speed had little effect on spindle moisture transfer. Combining three years' data on this study gives a regression curve of $Y = 2.72X + .03$, where Y = increase in seed cotton moisture and X = gallons of moistening agent used per bale. Although no definite correlation between relative humidity and seed cotton moisture transfer could be established, the combined three years' data showed that as the seed cotton moisture increases the ratio of transfer of moistening agent increases from .40 to .90.

4. Two studies of sources of trash contamination in mechanical picking were begun. In a basic study in Alabama, sources were identified by the process of eliminating the major contributing factors before harvesting. In well defoliated cotton, the total trash of the harvested cotton consisted of 27 percent leaf, 15 percent bracts, 31 percent burs, 3 percent limbs, 6 percent ground trash, and 18 percent unidentified trash. In cotton with abundant new growth, the total trash consisted of 37 percent leaf, 17 percent bract, 19 percent burs and 27 percent unidentified trash. In a study of trash concentration in the picker basket in Mississippi there was no difference in grade and staple of cotton ginned after dumping in a regular manner, as compared with cotton mixed or blended before ginning. This indicated that the trash accumulating in the rear of the picker basket is mixed in the ginning process and is spread uniformly throughout the bale.

5. In a basic study of the influence of plant characteristics on mechanical harvesting in Alabama, it was found that bolls located on limbs originating within eight inches of the ground had picker losses almost twice that of bolls on limbs originating at a height greater than eight inches from the ground. The losses from bolls located within a horizontal radius of six inches from the main stem were less than the losses from bolls located at a distance greater than six inches from the stem. A laboratory picker was designed to facilitate the study of spindle design characteristics and boll types. The picker exposes individually-mounted bolls to standard spindles to simulate the actual picking operation of a commercial picker. In Mississippi six varieties of cotton with widely different stalk and boll characteristics were compared with respect to their influence on mechanical picking. Although more trash was harvested with the smooth leaf varieties they turned out a higher grade after ginning. Open boll varieties with higher picking efficiency also had higher pre-harvest losses. Increased yield resulted in increased picking efficiency in most varieties. Mechanical picking tests of 25 varieties in Alabama revealed definite and important differences in harvesting efficiencies. For the 12 varieties recommended for

this area, machine efficiency ranged from a low of 89.6 percent to a high of 95.1 percent. The overall efficiencies were 85.4 percent and 93.6 percent for the low and high.

6. The experimental boll separator stripper elevator developed in Texas in 1961 was evaluated under more varied conditions to determine the performance of the machine and the effects on cotton quality and value for a wide range of crop maturities at harvest time. The separator operated at 90 to 95 percent green boll separation efficiency in field tests on two cotton varieties with green boll contents ranging up to 30 percent of the crop. Laboratory tests on the separator revealed that there was no significant differences in the separation efficiency of the separator when green boll contents ranged from five to 20 percent of the harvested material. Average separation efficiency of the machine for the laboratory test was 96.5 percent. In another evaluation of the machine, the experimental separator was compared with a conventional production model separator. The green boll separation efficiency of the experimental model was 97.8 percent compared to a separation efficiency of 71.0 percent for the conventional model. Two local shops are now producing a green boll separator elevators patterned after the experimental model. The pneumatic conveyance feature of the elevator makes the unit adaptable either for loading a tractor-drawn trailer in the conventional way or for conveying the material into a tractor-mounted basket. Another local shop, taking advantage of the elevator's versatility, is building a tractor-mounted basket for strippers. The two units are being used in combination to eliminate (1) the need for drawing a trailer, and (2) using one to two men for loading the drawn trailer.

7. A laboratory experiment was conducted in Mississippi to determine how preharvest environment affects cottonseed and lint. Temperature had a much more pronounced effect on seed viability and seed vigor than did relative humidity, while lint color, fiber strength, and fiber length behavior were apparently more closely associated with relative humidity than with temperature. For example, an increase in relative humidity from 60 percent to 80 percent within the 50° F. chamber affected viability only after approximately three weeks of exposure. On the other hand, an increase in temperature from 50° F. to 68° F. within the 60 percent relative humidity environment affected seed viability during the first week of storage.

C. DECIDUOUS FRUIT HARVESTING EQUIPMENT

1. Harvesting is the only step in the growing, handling, and packing of apples that has not been extensively mechanized. It is a serious problem because of high costs, periodical shortages of labor, and the difficulty of harvesting the entire crop at proper maturity. A total of 4,528 pounds of Ontario apples were harvested with a tree shaker, stored at 32° F. for four months, and processed into frozen slices. This fruit was compared to 5,342 pounds of hand-picked apples from the same orchard and handled in the same way. Machine picking caused some bruising and resulted in an increased

processing cost of $7.05 per ton. However, the savings in the orchard amounted to $7.50 per ton. It is hoped that further research in catching equipment should result in a reduction of the increased processing cost from $7.05 to under $1.00 per ton. Research again showed that pruning trees with the cutter bar hedger is feasible. Present cutter bars are not designed for cutting wood up to 2-3 inches in diameter. Motion and strain studies of the mower bar were made and useful design criteria is being obtained. Research continued on the pick-and-drop method of harvesting apples. A rotating table fruit receiver was developed which increased the pickers output by about eight percent over previous experimental equipment. A conveyor-type fruit receiver with adjustable height and elbow-type swing was developed for use in picking dwarf trees. It increased pickers output by 11 percent.

2. Cultivated blueberries are grown commercially in the Mid-Atlantic States, Great Lakes area, and the Pacific Northwest. Although this project has developed equipment and methods which greatly reduce the cost of harvest and packing blueberries, costs are still rather high and can be reduced further. Follow up studies of the mechanical picking unit developed on this project showed that 35 percent of the Michigan blueberry crop and about 20 percent of the New Jersey crop were harvested mechanically at less than half the cost of hand picking (3 1/2 cents per pound vs. 8 cents per pound). Considerable work was done on the experimental continuous blueberry harvester. A design was developed that proved effective; and if a commercial version can be constructed, it should reduce the cost of harvesting to under one cent per pound. The machine which straddles the blueberry bush has a set of free rotating spindles on each side. Each set of 80 spindles, 27 inches long is vibrated at a frequency of 3,000 c.p.m. (cycles per minute) through a 5/16-inch stroke. The automatic pint cup feed mechanism which was developed improved the performance of the experimental cellophaning unit and an equipment manufacturer is putting a packing machine on the market for next season which incorporates the principles of the cup feed and cellophaning unit.

3. Although research on prunes has led to the adoption of mechanical harvesting in the Sacramento Valley, prunes are still harvested by hand in the Santa Clara Valley where prunes fall to the ground as they mature over a month period. A commercially available frost protector blower (six foot propellor--air velocities of over 100 m.p.h.) was modified by installing nine-inch louvers that could either be rotated or oscillated in front of the air stream. Two different travel speeds (2 1/2 m.p.h. and 1 1/4 m.p.h.) were used with rates of oscillation and rotation of 60 per minute in harvesting four plots of 60 trees. The prunes were harvested every four or seven days. Results showed that this method was very selective in removing only the ripe fruit. However, the total removal was lower than desirable especially on the last harvest. The results were promising and further research will be conducted possibly with supplemental shaking.

Bark damage can be a serious problem when tree shakers are used to harvest or thin fruit. Late in the 1961 harvest Ceratocystis Canker was discovered in some prune trees at the point at which the shaker was attached to the tree. A testing unit was developed to apply radial and tangential forces to the limb. The actual force applied could be measured by the pressure in hydraulic cylinders of the unit. Evaluation of the injury to the tree (bark and cambium) was done by visual observations and also by inoculation of the test area with a solution containing the fungus spores. Results of the visual inspection indicate that on young prune trees bark discoloration occurs at approximately 300 p.s.i.; cambium discoloration occurs at 600 p.s.i. radial stress, and failure in tangential shear occurs at approximately 150 p.s.i. On older trees, discoloration occurs at somewhat greater stresses. For the inoculation tests, infestation by Ceratocystis occurred on older trees at a radial stress of approximately 1,000 p.s.i. and a tangential stress of 200 p.s.i. These critical stresses were about three-fourths as much on younger trees. Therefore, a clamp designed to not exceed 500 p.s.i. radial and 100 p.s.i. tangential stress would leave a margin of safety of approximately 2.0. To do this the contact area must be sufficiently large to distribute the clamping and shaking forces and tangential forces must be minimized. To accomplish the above objectives, a clamp with short continuous reinforced belts placed around rollers was designed and tested. The belts move on the rollers for alignment with the limb and being flexible, conform to limb shape. Field tests with this unit showed no visible bark injury and an inoculation test of limbs shaken showed no evidence of infestation. Another longer range project was initiated where threaded bolts were permanently installed in the trunks of various aged trees. Results thus far show the method might be feasible. Whether or not it is practical depends on economics.

4. From one-third to one-half the gross returns of both sweet and sour cherries are paid to workers who harvest the crop by hand. In fact, last year, growers received 4.7 cents per pound for sour cherries and paid 3 cents per pound to the hand pickers. Not only is the cost of hand-picking becoming prohibitive, but workers are becoming increasingly hard to recruit. The purpose of this research is to reduce harvesting costs and labor requirements through mechanization. Mechanical harvesting equipment for cherries which was developed on this project and which was used commercially last year to harvest several million pounds of fruit, was given further study. Accurate records were kept on the sorting and processing of 55 tons of machine-harvested cherries and 33 tons of hand-picked cherries. Results showed that Grade A packs were made when machine-picked fruit was processed. Harvesting equipment was improved to the point at which the units ran through the season without major breakdowns. Some equipment ran day and night for 20-24 hours a day. A study of terminal velocities of various fruits including cherries was completed and a report prepared for publication. Results show the terminal velocity of tart cherries is 510 inches per second, of grapes (Delaware) 600 inches per second, and of blueberries 375 inches per second. The results of this work are useful in mechanical injury, fruit separation, and cleaning studies. Over 120 different types of cushioning materials (foam, plastic, foam rubber, etc.) were subjected to impacts and rebound velocities

and impact forces were determined. The data is now being run through a computer and analyzed. Sweet cherries were harvested into and handled in bulk boxes at depths of 10, 12, 14, and 16 inches, transported 110 miles and brined. Results showed that sweet cherries can be handled in bulk boxes at depths of 14 inches with savings in time, labor, and money without loss in quality.

5. About 225,000 tons of Concord grapes are produced each year in the six States of New York, Michigan, Washington, Pennsylvania, Arkansas, and Ohio. Conventional harvesting and handling methods are expensive and cause considerable damage to the raw product. A grape box pick-up mechanism was constructed, mounted on a tractor and field tested. Using the machine saves time and money. A report of this study has been prepared for publication. Some trials on machine harvesting of Muscadine grapes indicate that shaker equipment can be developed for this crop when the acreage warrants it.

6. Harvesting Cling-Stone Peaches and Apricots. Hand labor for harvesting tender flesh fruits has been difficult to recruit. Previous research showed that mechanical shakers were feasible, but that bruising would be a problem. This season approximately 10 acres of cling-stone peaches were mechanically harvested by two different manufacturer's equipment. One operation used a trunk shaker and the other used two limb shakers. Harvesting rate was approximately 32 trees per hour; 216 boxes per hour or about 70 boxes per man-hour. The results showed that the shakers were non-selective as to fruit maturity and that bruising was five to ten percent more than hand harvesters. Injury occurring in the catching operation was studied and data obtained on energy relationships for fruit bruising and the ability of certain materials to absorb a higher percentage of the fruit kinetic energy. Results indicate that properly designed decelerator strips were the most effective for reducing injury. However, in areas where these strips cannot be used, a padding material which absorbs energy is preferred over one which momentarily stores energy and then releases it, accelerating the fruit upward into other falling fruit. Of the materials tests, an expanded polyethylene--was found to be the most suitable.

7. Mechanical Thinning of Peaches. Hand thinning of peaches and apples is expensive and labor consuming. Chemical thinning of peaches and early variety apples is considered impractical by most growers because of the inconsistency of the results. Tree shakers are now available for harvesting some fruit, and they can be used for thinning. A comparison was made among hand, machine, and machine followed by hand, methods of thinning. Technical aspects of thinning such as size distribution of the fruit removed, distribution of persisting fruits, etc. were determined. A comprehensive report on the mechanical thinning of peaches was prepared and published.

8. Harvesting Dates. Dates grow on palm trees which are 30-60 feet high and it is becoming difficult to find workers to pick fruit by hand in these tall trees. During 1962 experimental fruit removal equipment and complete harvesting systems were designed and tested to determine the feasibility of bunch

harvesting. Two vertical vibrators were designed and built which removed dates from the bunch mechanically. They deliver a 3 1/4-inch stroke to the bunch at 600-1,100 cycles per minute. One hundred percent removal was accomplished in about two seconds. Two men operating one vibrator can shake 450 bunches per hour. The two harvesting systems were as follows: One system features straight down-the-row operation of the "date tower" allowing all mature bunches to be harvested from two opposite palms at each stop. Fruit is removed from the bunch, by a vibrator, directly into bulk bins as the tower progresses down the row. The second system uses a smaller tower which allows harvesting 1/2 a palm per stop. Harvested bunches are hauled in trailers to a central location for shaking. Time studies of the two harvesting systems combined with other studies have shown: (1) Bunch harvesting is feasible, and (2) both harvesting systems will reduce total harvest costs relative to the hand-picking method. Harvest rates of 0.96 acres per hour (46 palms per hour) were attained where an average of one-half of the bunches on each palm were mature. The results were so promising that the experimental equipment was used commercially in harvesting 1 1/2 million pounds of dates. Also bulk boxes were used successfully for the first time in handling dates.

D. FORAGE HARVESTING EQUIPMENT

1. Field-curing studies of Coastal bermudagrass indicate that hay cut with rotary mower will dry faster than that cut with a sickle-bar mower, even if crushed or tedded. Due to many of the finely chopped particles not being picked up, the recovery yield for hay cut with the rotary mower was significantly lower than for that cut with the sickle-bar mower. Hay cut with the sickle-bar mower and crushed gave the fastest drying rate without a sacrifice in yield.

2. Studies on the optimum physical form and orientation of alfalfa for maximum drying rate showed that a 10-foot swath of forage, yielding 1.5 tons of dry matter per acre, raked into a conventional windrow would dry more slowly than when left in the swath. At dry matter yields of one ton per acre or less, the drying rate was not materially reduced when this practice was followed. Laboratory tests showed that forage given a severe mechanical treatment dried more rapidly than untreated forage. These mechanical treatments exposed more moist surfaces which gave a very rapid drying rate for a brief period, then slowed to a normal rate.

Hay wafering tests showed that many problems are encountered in this process. The operator must judge windrow density and moisture content and adjust speed and amount of water to be added. When variations in windrow are encountered, this becomes a demanding task. With increasing moisture content, about 10 percent (w.b), increasing percentage of grass or increasing crop maturity, the production of wafers became more difficult. For the season, average production rate was two tons per hour with a commercial wafering machine consuming an average of four gallons of fuel per ton.

E. FORAGE SEED HARVESTING EQUIPMENT

1. Research was conducted on harvesting equipment to determine the efficiency of the cutting and feeding mechanisms in gathering crops for the purpose of improving the equipment and methods in order to reduce the seed shatter and damage losses. At Corvallis, Oregon, there were no investigations made during the year. At Clemson, South Carolina, the research was confined to making some minor alterations to the low cost row-crop corn-header combine attachment previously developed and observing its performance. The attachments are receiving good farmer acceptance and are now being manufactured commercially.

2. Improved Techniques for Harvesting Seed Crops. A survey of seed harvesting in the Willamette Valley of Oregon indicated that 50 percent of the small grass and legume seed produced is lost in the harvesting operation. In an effort to reduce the excessive seed losses, a scientific study was made under atmospheric controlled conditions in threshing crimson clover at Clemson, South Carolina. The study was made to determine the effect of cylinder speed and cylinder concave clearances on seed loss and damage. A rubber concave and cylinder bar threshing cylinder used in the tests produced excessive seed damage with a low percentage of unthreshed seed when the peripheral speed was 6,000 f.p.m. or higher, regardless of the concave clearances. At 4,000 f.p.m. the percentage of unthreshed seed was excessive even with the zero cylinder concave clearance. In tests involving a combination of five clearances and five peripheral speeds, best results were obtained with zero concave clearance and 4,500 f.p.m. peripheral speed.

At Corvallis, Oregon, research was continued on crimson clover harvesting. In an effort to reduce the high unthreshed seed loss in harvesting, a special rubber-covered cylinder and concave bar machine was compared to standard spike-tooth and rubber-covered angle bar threshing cylinders. Best results were obtained with the special rubber-covered cylinder bars when running 5,000 f.p.m. with a one-eighth-inch concave cylinder bar clearance. The maximum threshing efficiencies were as follows: 80.5 percent for the special bar, 69.2 percent for the spike-tooth cylinder, and 64.5 percent for the angle-bar cylinder.

Research on belt threshing was initiated at Clemson, South Carolina, to determine seed loss, damage, and machine capacity. The unit will thresh by a rubbing action which will reduce seed damage. The first model of a test unit has been constructed and will be tested during the coming harvest season.

At both Clemson, South Carolina, and Corvallis, Oregon, research is underway on the development of a vertical rotating screen separator. If successful, the machine will have an improved separation efficiency and a higher capacity than that of a flat screen of the same size and area. The separating force can be regulated from zero up to 15 or more times that of the pull of

gravity by adjusting the revolving speed of the screen. Preliminary test results look promising, however there are many problems yet to be solved before it is ready for general use. One of the major problems seems to be that of keeping the screen clean.

In a six-year study in methods of harvesting lotus or birdsfoot trefoil using many methods, windrowing the crop on clear plastic, then combining, gave the best results. The average yield by the several harvesting methods are as follows: 55 percent when windrowed on clear plastic, then combined. The yield was only slightly less for white plastic, kraft paper, and black plastic; 50.2 percent when put in very loose bales and later threshed through a combine; 49.5 percent when windrowed and threshed by using a combine with a suction attachment; 44.4 percent when windrowed, shocked and later threshed with a combine; 38.2 percent when windrowed on the ground and later threshed with a combine; 37.0 percent when defoliated and combined; 35.1 percent when combined direct without defoliation; 19.5 percent when combined direct with a suction attachment; and 9.3 percent when the crop was windrowed, baled and later threshed with a combine.

3. Optimum Moisture Content for Seed Harvesting. At Corvallis, Oregon, time of harvest research was continued with lotus and initiated with bluegrass and orchard grass. In lotus, the production of pure live seed per acre increased each time the crop was harvested until approximately 10 percent of the pods had shattered where 58.2 percent of the crop was saved; then the quantity of seed decreased until the entire crop had shattered. In the bluegrass harvesting research over a 26-day span, the bluegrass was harvested seven times. The highest percentage of pure live seed (74.9 percent) was obtained on the first cutting. This compares to an average of 55.8 percent for the farmer. Orchardgrass was harvested six times over a 19-day period with pure live seed ranging from 65.1 percent at first cutting up to 68 percent, and then down to 27.3 percent on the last cutting. This compares to a 55.8 percent pure live seed check over a farmer's two-year harvesting study. A battery-operated moisture meter was used to take readings on samples at each cutting and duplicate samples were oven-dried for correlation with the meter reading. These data will be used in plotting a curve for each crop for use with the meter in making on-the-spot moisture tests to be used as a guide to harvesting.

F. LONG FIBER CROPS HARVESTING EQUIPMENT

1. The development of improved harvesting and processing machinery and methods for the production of kenaf and other jute-like fibers has been allocated most of the funds and personnel available for long fiber research.

About 12 tons of retted fiber produced at three locations, namely, Belle Glade, Florida; Palm Beach County Farm, Florida; and Tifton, Georgia; were shipped to two mills for experimental spinning tests. The acre yield averaged 1,250 pounds and costs were estimated at eight cents per pound. The grade of fiber compared with kenaf imported from the Orient showed a value of 10 cents per pound, the quality being in every way equal to the imported

product. Improvements on the equipment included the development of a mechanical splice for the grip belts; replacement of gasoline engine drive for second ribboning drum by a hydraulic motor; and clearing passageway through the machine to prevent trash or other material fouling chains, shafts, etc., thus reducing stoppages for cleaning. Performance of the harvester-ribboner was considered very satisfactory as only minor difficulties were encountered throughout the season. The harvesting rate was .86 acres per hour. The mechanical washing equipment was rebuilt, eliminating the scutching unit and adding several pairs of squeeze rollers. The entire unit worked very well but the handling of the fiber from the harvester through retting and cleaning needs improvement. A complete harvester-ribboner and washing unit patterened after the USDA equipment have been built by a farm equipment manufacturer under contract to AID for use in Sudan. It is anticipated that the equipment will be used to harvest and process about 200 acres of kenaf.

2. The objectives of the sansevieria harvesting program are to develop a combine type harvester-decorticator, to determine the best method of treating the field harvested fiber to the baling stage; and to determine harvesting techniques that will result in the best regrowth of new plants from the rhizome bed. Due to major project emphasis being placed on other fiber crops, work this year has been confined to the redesigning and rebuilding of the experimental harvester-decorticator to handle a heavier volume of leaves. Conversion of the machine to a self-propelled unit was also initiated. This is needed to keep the swath of plants accurately in line with the gathering chains and the divider separating the cut leaves from those left standing. The sansevieria plantings at all locations suffered moderate to severe damage from the cold spell in December when the temperature dropped to 28° F. Regrowth of the damaged plants is under study.

G. OILSEEDS AND PEANUT HARVESTING EQUIPMENT

1. Development and improvement of peanut diggers continued with tests of four different makes of peanut diggers showing that the recovery efficiency was relatively high. Losses by weight of unshelled peanuts salvaged from the soil ranged from 3.0 to 5.7 percent. Some of these losses are due to natural shedding. Peanut plants from which the tops were clipped prior to digging lost significantly more peanuts in the digging operation than unclipped vines.

Methods of accelerating the drying rate of windrowed peanuts consisted of the formation of four different types of windrow: nuts up; clipping vines prior to digging; nuts down; and, the conventional method which results in nuts being mixed in the windrow. For the first 24 hours, the drying rate was about the same for the nuts in each windrow. The peanuts turned up appeared to dry faster from the first to the fourth day, but from the fourth day to the eighth day the drying rate for each type of windrow was approximately the same. Although there was a tendency for a faster drying rate with the peanuts turned up, there was no significant difference of the drying rate of the windrows within any one day or from day to day.

2. Combine harvesting of high moisture peanuts. Combine studies conducted with the Virginia type peanuts to compare grades and recovery yields when harvesting freshly dug peanuts and those combined at 1, 2, 4, 6, and 8 days after digging have shown that recovery yields were not significantly affected by harvesting dates. Although not statistically significant, slightly lower yields were obtained from combining freshly dug peanuts than from harvesting after partially curing them in the windrow. Good recovery yields were obtained beginning as early as the second day after digging.

3. Castor Combine for Harvesting Damp or Dry Castor Beans. Frequent periods of adverse weather (high humidity and wet plants) experienced late in the fall during the castor harvest season results in delayed harvesting and increased field losses using existing harvesters. A four-row harvesting attachment was designed and built for a commercial grain combine which cut off the plants and passed them through the machine for removing the capsules, hulling and cleaning. Over 17 acres were harvested with only minor row losses. Several companies have indicated their intention of building experimental machines this year employing the principles of the castor combine.

Defoliating Castor Beans to Condition for Harvesting. Chemical spray material is required to condition plants and dry the seed capsules when harvesting before killing frosts. Past grower experience has shown that the effectiveness of defoliation with chemicals may vary for different times of the season and between seasons. Defoliation applications tested in cooperation with CRD at Davis, California, the previous year were not as effective during the current seasons. Either a second application or a greater concentration of defoliating chemicals was required for effective results.

Effect of Screw Conveyor Entrance Section Design on Castor Seed Breakage and Capacity. The fragile oil-bearing seeds are easily damaged. Broken fragments tend to cause build-up which interferes with conveying. Seed damage results in oil loss, discoloration, and reduced quality. Basic relations of the effect of entrance section design, screw speed, and entrance opening height on castor seed damage and conveyor capacity were established and expressed in the form of polynomial equations. This information may be used in the design of screw conveyors to reduce castor seed damage.

Effectiveness of Two-Drum Hullers in Hulling Castor Beans. Two-drum hullers used on castor harvesters tend to leave more capsules unhulled than other types of hullers but have the advantage of operating without requiring precleaning to remove sticks and trash. Further analyses by multiple regression were made of previous data to evaluate the effect of hulling rate, clearance, and drum speed on drum huller performance. Polynomial equations with high correlation coefficient were established.

4. Development of Tung Harvester. Practically all of the tung crop is harvested with hand labor. This represents the major cost of tung production. One of the biggest problems in developing a tung harvester for effective operation is the wide range of harvesting conditions (from extremely dry and dusty to very wet) that often exists in any one harvest season. Factors

affecting the cleaning ability of a perforated drum type cleaner, such as speed, angle, and air requirements were studied. The information gathered will be used to further improve the machine efficiency and performance mainly in gathering and cleaning mechanisms.

Self-propelled Tung Windrower. The rake type reel previously developed for mounting onto a tractor was incorporated in a self-propelled windrower. This machine was entirely satisfactory in windrowing on properly prepared land when the leaves and tung were either wet or dry.

5. Hauling and Handling Harvested Tung Fruit. The study on development of a bulk handling system of using pallet boxes for moving tung fruit from harvester to fieldside truck or farm storage was found to be effective for the second year. A low cost portable platform developed this year provided convenience of loading adjoining the field harvesting areas to save travel time. A pallet box with expanded metal sides and wooden bottom was lighter in weight and proved to be more sturdy than previous models.

H. POTATO HARVESTING EQUIPMENT

1. Multi-Row Harvesting of Potatoes. A two-row digger with a long-reach windrowing attachment was improved by increasing wheel and tire size. Several other units were made up by growers and manufacturers. These units were used in harvesting a considerable acreage and made possible the harvesting of six rows at one time which resulted in increased harvester capacity while at the same time reducing the total machine cost and wear.

Spillout Losses and Roller Shares in Potato Harvesting. Follow-up studies again showed that using paired roller shares in open front type two-row diggers eliminated center spillout and vine clogging. Several commercial manufacturers are now making roller shares available for this type of harvesting equipment.

2. Mechanical Injury of Potatoes. Bruising continues to be one of the major problems in storing and handling potatoes. Investigation of the relation of susceptibility of potatoes to bruising and shear strength of potato tissue did not show any correlation. Apron links of 2 1/2-inch pitch with molded-on rubber cushioning in the form of rubber flats cantilevered rearward from the link were designed and made up. Preliminary tests indicate that these links result in good cushioning and therefore, less bruising, have a high capacity for soil separation, and have potential for sizing.

3. Engineering Cost Study of Harvesting and Handling Potatoes. In cooperation with the Economic Research Service an engineering cost study on harvesting and handling potatoes has been initiated. This study will include tables and charts that growers may consult and determine the costs of their operation based on capital investment, capacity of machines, acreage, and yield. From this study a farmer may determine his best combinations of equipment and methods of operations for the acreage under cultivation. The data covers potato farms from 95 to 700 acres and a publication is now being prepared for early release.

4. Minimum Tillage for Potatoes. The study of deep tillage in the spring, deep tillage in the fall, fall plowing, and no tillage (planting directly in the wheat stubble) was repeated for the second year. Although planting conditions were different (6.52 inches of rainfall in May 1962 as compared to .81 inches in May 1961) results again showed that the amount of clods and yields per acre were not effected by pre-plant tillage practices. In fact, in both years potatoes planted directly in wheat stubble resulted in the greatest yields.

I. SUGARCANE HARVESTING EQUIPMENT

1. Cutter-Cleaner-Loader Type Sugar Cane Harvester. Major design and construction changes consisting of a gatherer system and a planetary drive for the main ground drive wheels were made on the USDA experimental sugar cane harvester. The purpose was to reduce ground loss, to improve the handling of lodged canes, and to improve the overall machine efficiency and performance. These investigations are in cooperation with the American Sugar Cane League who provided both program direction and financial assistance.

Gatherer Assembly for Down Cane. A telescoping gatherer assembly was developed with a wide adjustment range for permitting the lower unit to be positioned near the ground for picking up lodged canes but at the same time provide sufficient topper adjustment range for correct topping. A gatherer drive independent of the forward travel of the machine provided speed changes needed for assistance in gathering the lodged canes. Although significant progress was made in gathering down cane with the telescoping attachment further improvements are apparent and will be pursued.

Harvester Losses Due to Strippers. In three comparable tests of stripper arrangement, the average quantity of trash was 5.0 percent for upper and lower strippers as compared with an average of 6.9 percent when the strippers were omitted. The quantity of trash for all tests averaged 4.0 percent, which ranged from a minimum of 2.9 percent to a maximum of 14.4 percent as compared with the plantation season average of 7.7 percent. The life of the snap-in type rubber finger strippers averaged 9.0 tons per finger before breaking. This represents a direct finger replacement cost of 3.6 cents per ton of sugar cane harvested. Further study of efficiency of both upper and lower strippers are necessary to establish their effectiveness on different varieties of cane and a wider range of crop conditions.

Harvester Efficiency. Harvester efficiency for six field tests averaged 95.8 percent, ranging from 88.9 percent for badly lodged and bored sugar cane variety C.P. 48/103 to a maximum of 97.3 percent for erect but bored C.P. 52/68 variety. The results on the effect of stripping on ground loss were not statistically significant. Field observations indicated variations of bored damage and cane erectness within the field may impose greater differences than those being measured.

J. TOBACCO HARVESTING EQUIPMENT

1. Development of a Mechanical Tobacco Harvester. The function of an experimental harvester is to stalk cut unprimed tobacco, automatically pierce the stalks and place them at regular intervals on conventional wooden sticks. This is a project initiated by the Agricultural Experiment Station, University of Kentucky in 1960, in which ARS personnel are now cooperating. Satisfactory operation of the machine in 1962 was limited to a capacity of three sticks per minute when harvesting primed plants. A new type of spearing mechanism has been designed and successfully laboratory tested. The function of the new spear, termed a "spiral held floating spear" is to permit design capacity of six sticks per minute when operating in unprimed fields. It is proposed to use this spear in future research.

Physical properties of mature burley tobacco plants are needed by design engineers in order to establish design criteria for machines to handle the crop. The objective of current investigations is to define and qualify these properties in engineering terms which will be useful in machine design.

Stalk Strength Properties. Material from the woody portion of tobacco stalks was tested in flexure to determine its modulus of elasticity and proportional limit. Determinations were made for three varieties; Kentucky 10, Kentucky 21, and High Leaf. Small test specimens were sawed from the woody portion of the stalks and sanded to size, approximately 1/4 x 1/4 x 3 1/2-inch test span. Precise measurements of the dimensions were made at time of testing. Moisture content was maintained near field conditions until tests were made and moisture content and density were determined for each test specimen.

Values for modulus of elasticity for the three varieties were determined as follows: Kentucky 10, 386,000 p.s.i.; Kentucky 21, 309,000 p.s.i.; and High Leaf 402,000 p.s.i. Values determined for proportional limit were: Kentucky 10, 2,149 p.s.i.; Kentucky 21, 1,537 p.s.i.; and High Leaf 2,122 p.s.i.

Leaf Responses. The resistance of leaf lamina to external forces was investigated. Leaves from three stalk positions were used and tests were made at different stages of wilting from freshly harvested leaves up to five days of wilting. Both static and dynamic forces were used, with ten levels of loading. Forces were applied to test areas of one square inch in area. After forces were applied the leaves were hung in a curing shed and air-cured. When the leaves were cured they were evaluated for injury due to bruising, based on perceptible difference in color of the test areas. Minimum force to cause discoloration was recorded.

It was found that fresh or turgid leaves were more resistant to bruising than were wilted leaves. Generally speaking, resistance decreased with wilting time; however, it was found to fluctuate considerably in a systematic manner, during the five day wilting period. The static force to cause bruising varied from a maximum of 155 p.s.i. for freshly harvested leaves to a

minimum of 30 p.s.i. for leaves wilted four days. The energy to cause bruising by dynamic loading varied from a maximum of 0.46 in.lbs/in^2 for freshly harvested leaves to a mimimum of 0.15 in.lbs/in^2 for leaves wilted three days.

A study was conducted to determine the force required when applied perpendicular to the midrib, to break a leaf from the stalk and the angle the leaf would deflect before rupture occurred. The forces were applied in three directions, up, down, and around the stalk; and at three distances from the point of attachment to the stalk, two, four, and six inches. Leaves were selected from the portion of the stalk from 12 to 18 inches above the ground.

It was found that all leaves could be bent upward until they touched the stalk without rupturing. The angle which the leaves could be deflected downward without rupture compared closely with the angle which they could be deflected around the stalk. Also, the forces required to cause rupture compared closely for the two directions, downward and around the stalk. These angles varied from a mean of 47^o for the two-inch distance to a mean of 84^o for the six-inch distance. The force required to rupture the midrib varied from a mean of 500 grams for the six-inch distance to a mean of 1,093 grams for the two-inch distance.

Handling of Stalk-Cut Air-Cured Tobacco on Vertically Suspended Strings. The objective of a proposed system of harvesting, handling, and curing stalk-cut tobacco on vertically suspended strings is to reduce labor requirements during harvesting and curing. The system consists of a harvester whose function is to mechanically cut the stalk, automatically fasten the base of each stalk to a continuous string at pre-set intervals, and to convey the "chain" of stalks to a wagon pulled alongside the harvester. The proposed system will utilize an aircure barn having a horizontal rail system near the roof. A movable drum hoist is to be used to pull the tobacco from the wagon to the rails.

The system uses a geometrical configuration of stalks during curing unlike any currently being used. In the fall of 1962 a preliminary test was conducted to determine the feasibility of air-curing when the stalks are placed in an air-cure barn in this manner. Tobacco was placed in a conventional barn having all but the top rail systems removed. The tobacco was suspended from the system at lateral and longitudinal intervals of two feet. Two treatments of stalk interval on the string were tested, 16 inches and 20 inches. The quality of cured tobacco from both string treatments as determined by official government grading did not appear to be different from that cured conventionally.

Handling of Stalk-Cut Air-Cured Tobacco on Pallet-Rack Curing Frames. The objective of a system of handling and curing stalk-cut tobacco on pallet-rack curing frames is to reduce labor requirements during housing. Tests were conducted at the farm of a cooperator. Stalk-cut tobacco was manually placed on pallet-racks in the field at twice the normal curing density. The filled pallet-racks were then hauled on wagons to a clear-span curing barn, the

pallet-racks placed in the barn with a fork-lift tractor, and the empty wagons reloaded with empty pallet-racks for return to the field. The system tested required four men in the field, three tractor operators, and a fork-lift operator. During housing, 26.3 man-hours were required to house one acre of tobacco, a reduction of approximately thirty-four percent from that normally required by conventional methods. Quality of the cured tobacco as determined by official government grading was approximately equal to that cured conventionally.

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AREA 5, CROP PREPARATION AND FARM PROCESSING (EXCEPT COTTON)

Problem. The programs of research in this area are concerned with the development of better methods, techniques, and equipment for use on farms for the initial preparation for market or the processing of farm products to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. The underlying principles that pertain to the cleaning and drying of different crops, curing of tobacco and peanuts, and sorting need to be determined. The methods for processing farm crops are largely dependent on production practices and dictated by future handling or storage requirements. Consequently this requires interdisciplinary collaboration in the creating of a completely mechanized program of crop production.

USDA PROGRAM

The Department's effort in this area constitutes a long-term program involving agricultural engineers and statisticians engaged in both basic and applied research on the engineering phases of crop preparation and farm processing. Seed cleaning research is currently being conducted at Corvallis, Oregon, in cooperation with the Experiment Station and private industry. Research on tobacco curing and sorting is cooperative with the Experiment Station at Lexington, Kentucky. The decorticating, retting, and cleaning of long fiber crops is carried on at Belle Glade, Florida, in cooperation with the Everglades Branch Experiment Station, the Office of Defense Mobilization, and industrial fiber users. Research on the drying of grain is cooperative with the Experiment Station at Ames, Iowa, equipment manufacturers, and farmers. Forage drying is under study at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Coastal Plains Experiment Station. Manufacturers cooperate through loan of drying equipment. Research on the drying and hulling of tung nuts is conducted at Bogalusa, Louisiana, in cooperation with the Experiment Station and industry. Drying of castor seed is cooperative with the Oklahoma Experiment Station. The pelleting of forage crops research is conducted at Tifton, Georgia, in cooperation with the Coastal Plains Experiment Station and equipment manufacturers.

The Federal engineering effort devoted to research in this area totals 10.8 professional man-years. Of this number 2.1 is devoted to seed cleaning, 2.0 to curing and sorting of tobacco, .3 to decorticating, retting, and cleaning long fiber crops, .2 to drying of castor seed, 4.0 to drying of grain, .5 to drying forages, .2 to drying and hulling tung nuts, 1.0 to pelleting forage crops, and .5 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. SEED CLEANING

1. Seed Cleaning Research Applied to Specific Problem Mixtures. At Corvallis, Oregon, problem seed mixtures were processed through the laboratory and reports and recommendations were made to the seed processors on how to handle them. The scientific method of microscopically measuring seed was used to determine the type of machine and the sizes of indent pockets or screens to use in order to exploit any dimensional differences in making a separation. Screen dams were successfully used to retard the flow of seed across a screen and to orient elongated seeds so that they would up-end and go through a round-hole screen. Some typical screen-dam separations were yellow star thistle from alfalfa; Alta fescue from Chewings fescue; wheat from safflower; quackgrass from bromegrass; ryegrass from fine fescue; and barley from lentils. The vibrator separator that separates materials by sensing their shape and surface texture continued to give highly satisfactory results. It will concentrate quackgrass in ryegrass, orchardgrass, and fine fescue mixtures. It will separate curly dock from bluegrass; silver hairgrass from bentgrass; and multiple florets from singles in fine fescue grasses.

2. Centrifugal-Pneumatic Separator. There was no research conducted on the centrifugal-pneumatic separator during this reporting period. The plan for future work is to use a vacuum in lieu of air pressure as a means of removing lighter seed from the revolving screen.

3. Modification of Seed-Length Separators. At Corvallis, Oregon, special indent cylinders are being constructed to correspond to the microscopic measurements of seeds so that the cylinder will make a specific length separation of a seed and its contaminant. These special cylinders have been successful in making many separations which were not possible with existing equipment. Some of the separations using special indent cylinders were pigweed from alfalfa; yellow cress from Highland bentgrass; big mouse-ear from Astoria bentgrass; cocklebur from cottonseed; and sandspurry from Seaside bentgrass.

4. Development of Vibratory Feeders for Use in Studying Seed Cleaning and Handling Machinery. At Corvallis, Oregon, numerous feeding and metering devices are needed to feed several dozen prototype seed processing machines. The electric-powered pulsating magnet vibrator feeders are ideal for the purpose but are expensive. Inexpensive mechanical vibrator feeders were developed which can be shop-constructed at about one-eighth the cost of commercial vibrator feeders.

B. TOBACCO CURING

1. Measurement of Leaf Coloring Rates with Time-Lapse Photography. Basic information concerning the tobacco leaf response to the curing environment is needed before steps can be taken to develop curing systems which are

compatible with mechanized handling of Burley tobacco. One fundamental response which has been measured is the coloring rate of the leaf in a controlled environment. Preliminary results have indicated that the coloring rate of primed Burley tobacco can be measured by one-frame exposure of 16 mm. movie color film at two-minute intervals over a five-day period. The developed film was used to show the coloring rate visually as a movie at 16 or 24 frames per second. Also, the transmittance of the 16 mm. color film image of the leaf was used as a relative measure of the leaf coloring rates. These measurements indicated that the yellow-to-brown color transition occurred after about 40 hours in an environment of 105° F. and 80 percent relative humidity.

Certain Thermal Properties of Tobacco During the Cure. The objective of this investigation is to determine certain thermal properties of tobacco during the cure--namely, thermal conductivity, specific heat, and thermal diffusivity. These basic properties are necessary in the analysis, design, and development of facilities for controlling the environment and curing process of tobacco. The apparatus used in this investigation was a guarded hot plate designed and constructed after ASTM standard specifications but with a few modifications to account for the biological characteristics of the test specimens. Each test specimen was formed from approximately 25 to 75 individual discs four and one-half inches in diameter cut from the leaf lamina. They were stacked to a thickness of approximately one-half to five-eighths inch when compressed under five p.s.i. pressure.

Although a thorough tabulation of the data has not been completed, initial computations show the thermal conductivity to be in the range of 0.57 to 1.08 B.t.u./(hr.) $(ft.^2)$ (°F.)/in. for freshly harvested to cured tobacco (Kentucky 10). The moisture content (wet basis) and bulk density of the specimens were 27.0, 33.7, and 54.5 percent, 45.5 $lbs./ft.^3$, respectively.

C. DECORTICATING, RETTING, AND CLEANING LONG FIBER CROPS

1. Improved Processes and Techniques for Cleaning Ramie Ribbons. During the past year studies on improving processes and techniques for cleaning ramie ribbons has been devoted to work on an in-line type degummer developed by the late Charles Short. This process degums ramie fiber from well decorticated material, and is also applicable to kenaf fiber. The original machine has been redesigned by Experiment Station personnel and a private individual, but needs to be completely rebuilt and stainless steel chains and sprockets installed. This project has contributed material and personnel in making the machine operable for the limited tests made thus far. The process in its present state does not clean ribbons well enough for commercial use, but improvements in this machine and in the field ribbons produced appear possible. The three and one-half acre planting at the Everglades Experiment Station is being maintained as a source of material for harvesting and degumming tests.

D. GRAIN DRYING

1. Studies are underway at Ames, Iowa, for determining the factors that enter into rational design of drying equipment and for developing quantitative descriptions of their relation to economic design. For example, during in-storage drying, overdrying and reabsorption of moisture puts excessive stresses on the drying bin. Costly failures can be avoided by either modifying the drying procedure or by modifying bin design. Equipment was set up to expose corn samples to constant temperature, constant humidity, and constant air velocity. The samples were weighed periodically to determine the pattern of moisture loss. So far 10 tests have been made. Each test included four initial grain moistures and four air velocities, 16 samples in each test. Some tests have been continued for as long as four weeks. Each sample weighed about 50 grams at the start. The results so far seem to follow nearly the same pattern as found previously for grain sorghum. If this pattern is confirmed, it will lead to a better understanding of the mechanism by which the moisture leaves a grain kernel during drying. No further observations were made on pressures in bins due to expansion of rewetted corn. From previous observations such studies will have to wait for equipment in which the effect of flexibility of the bin can be taken into account.

2. Drying in Model Bins: Tests of drying shelled corn with various degrees of heating show a consistent relation between traverse time and depth of the drying zone. Four bins of corn with an initial moisture content of 22 percent were dried at various temperatures. The dewpoint was 45° F. for all four. The heated air temperature was such that the air temperature drop in going through the grain was approximately 9°, 20°, 41°, and 84° F. in the respective bins. The air in each bin dropped to approximately a constant temperature before it reached the top layer of grain during the early part of the drying period. The depth of the drying zone, the region in which the grain temperature is not constant, remains about constant until the top layer starts to dry. The depth of the drying zone in all bins was observed to be the distance the air moved in 1.4 seconds. This suggests that the depth of the drying zone is independent of the entering air temperature. It can be computed from this that the drying zone extends the entire depth of the bin when an airflow of 22 c.f.m. per bushel is used throughout the range of temperature used. If the volume of airflow is less than 22 c.f.m. per bushel, the bottom will be dried nearly to equilibrium before the upper layers start to dry.

3. The time limitation on deep bed or in-storage grain drying systems is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The factors which influence the rate of growth of the microflora are grain moisture, temperature, and the amount of physical damage of the grain. At Ames, Iowa, studies are underway toward evaluating the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration. In 1962, the laboratory studies of carbon dioxide production was expanded to 96 samples. The range of

temperatures was increased to from 35° to 110° F. and the range of moistures was from 16 to 28 percent. A pattern similar to that of last year was observed. That is, at moistures of 22 percent and above it appears that the grain respiration can be distinguished from the mold respiration. At lower moistures no consistent pattern has been detected. Some field-shelled samples and some hand-shelled samples were tested. The field-shelled samples had had mechanical damage comparable to corn from the usual harvest operations. The hand-shelled corn was free or nearly free of mechanical damage but otherwise like the field-shelled samples. The rate of CO_2 production and presumably of deterioration was from two to three times as great in the field-shelled as in the hand-shelled samples. This suggests a potential improvement that might be accomplished if shellers could be designed to operate without damaging the corn.

E. FORAGE DRYING

1. Studies of wafer handling, drying, and storing properties showed that with the wafers made, gravity flow handling methods could not be used. Cribs do not permit sufficient ventilation to prevent molding when used as a storage for fresh wafers. Mechanical drying of wafers in a grain bin was slow because of the accumulation of fines and the resulting reduced air-flow. The use of a mechanical distributor did not alleviate the separation of wafers and fines. The slow movement of moisture from the center of dense wafers allows them to become dry on the outside and still contain too much moisture. Mold appeared on fresh wafers in 48 hours under controlled temperature and humidity conditions. These tests indicated that the only processing advantage of wafers is a reduction in the required storage volume. Future investigations will include physical quality, handling durability, the extent of surface drying, the rate of moisture removal, and the potential of pulse drying.

Samples of hay processed through a commercial expansion process, to free lignin, did not show an increase in digestibility when fed to sheep.

F. DRYING AND HULLING TUNG NUTS

1. Conditioning Tung Fruit for Storage: Conditioning high moisture tung fruit for safe storage by economical means can best be accomplished when basic factors affecting release of moisture from tung fruit is understood. Investigations were initiated to determine the rate of heat penetration of tung hulls and kernels having different moisture contents. Data obtained previously on drying characteristics were analyzed in forms of graphs to show the relation in rate of moisture removal and static pressures for different depths of tung to several air flow rates. This information is to be used as a guide for further studies to cover a wider range of drying conditions.

2. Tung Hullers: Hauling requirements from farm to mill could be reduced up to 50 percent by removal of hulls. This can be accomplished only when hullers are developed which will not damage the fruit to cause oil quality deterioration. Tests on an experimental field huller showed the machine to have a capacity of 2.2 tons per hour when hulling wet fruit of 38 percent moisture (wet basis). The average kernel loss was .59 percent and the kernel to shell (covering of the kernel) was 77 percent. The machine performed better on high moisture fruit than dry.

G. DRYING CASTOR SEED

1. Resistance of Hulled and Unhulled Castor Beans to Air Flow: At times, castor seed during harvest contain moisture in excess of the amount acceptable to processors. Such material may deteriorate in storage unless the excess moisture has been removed. Initial investigations using a pilot dryer showed the resistance to air flow in loosely filled bins for hulled seed is at least twice the resistance for unhulled castor beans with the same quantity of air flow. Exponential equations with high correlation coefficients were developed to express the relationship. Further studies are planned to obtain the effect of moisture content of castor material on resistance to air flow; also drying requirements to condition castor beans. A study is planned to determine the effect of heat, moisture, and storage on quality maintenance of castor beans.

H. PELLETING FORAGE CROPS

1. Coastal bermudagrass dehydrating, grinding, and pelleting studies with full-scale equipment showed that the equipment should be operated at near maximum capacity for top efficiency. With the production rate varying from 1,068 to 1,267 pounds per hour (average 1,185), 6,923 cubic feet of gas and 149.9 kw.-hr. were required per ton of dry matter. With the production rate varying from 432 to 1,516 pounds per hour (average 1,112), 10,567 cubic feet of gas and 199.6 kw.-hr. were required per ton of dry matter. Thus, although the average rate was almost the same, the wide range in production rate required 51 percent more fuel and 33 percent more electric power.

Pelleting sun-cured Coastal bermudagrass was more difficult than pelleting dehydrated hay. The production depended largely on the quality of the hay. About 50 tons of sun-cured, baled Coastal bermudagrass hay, which in general was poor quality, was pelleted. The average production rate with a 30-h.p. motor on the pellet mill was 375 pounds per hour. When a 50-h.p. motor was installed, the average rate was 480 pounds per hour. About 4 1/2 tons each of high quality, 4-week-old and 6-week-old, excellent color Coastal bermudagrass was pelleted (50-h.p. motor on the mill) with an average production rate of 830 pounds per hour.

Grinding and pelleting energy studies on bermudagrass hybrids indicate that there was a significant difference in grinding energy requirements. However,

there was no significant difference in the pelleting energy. When the pelleting and grinding energy for these hybrids were added, there was no signficant difference.

Systems of utilization of Coastal bermudagrass showed that more pounds of beef could be produced by dehydrating and pelleting than by any other method tested. Dehydrated and pelleted Coastal bermudagrass fed to steers in dry-lot produced 472 pounds of gain plus 2.22 tons of pellets (dry matter basis) per acre. Continuous grazing produced 451 pounds of gain and no surplus hay per acre. Rotational grazing produced 379 pounds of gain and 1.19 tons of poor quality hay per acre. Chopped, dehydrated hay produced 364 pounds of gain and 3.05 tons of hay per acre. Strip grazing produced 268 pounds of gain and 1.63 tons of poor quality hay per acre. Green chop produced 193 pounds of gain and 2.10 tons of hay per acre. Had all pellets and dehydrated hay been fed, and the same feed conversion rate maintained, the gains from these two systems would have been 783 and 764 pounds per acre, respectively. These results indicate that the value of 332 pounds of beef could be applied toward the costs of dehydrating and pelleting and the value of 313 pounds of beef could be applied toward the cost of dehydrating only.

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AREA 6, COTTON GINNING

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed and trash, packaging, and sampling to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Advances in cultural practices in the mechanization of cotton harvesting will depend to a great extent on continued research to develop adequate ginning equipment, improvements in present equipment, and improved practices in using equipment. The solution to many of the difficult problems of modifying the gin to meet the needs of mechanically harvested cotton are still ahead.

Cotton ginning problems are greatly influenced by the recent increase in mechanical harvesting on one hand and the desire of the spinners to increase their manufacturing efficiency on the other. Since it is recognized that the present day seed cotton comes to the gin containing more trash and moisture than formerly, it follows that conventional ginning processes cannot be expected to deliver to the industry a product with the same qualities that characterized the cotton of former years. A close analysis will show that the most pressing problem areas with regard to ginning are those pertaining to controls for drying and equipment for cleaning both the seed cotton and lint.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, materials engineers, and systems engineers engaged in both basic and applied research on the engineering phases of cotton ginning and handling. Seed cotton handling and storage is currently being conducted at Stoneville, Mississippi; Clemson, South Carolina; Mesilla Park, New Mexico; and Chickasha, Oklahoma. Research on seed cotton drying, seed cotton cleaning and gin performance and cotton quality is conducted at Stoneville, Clemson, and Mesilla Park. Conveying equipment and gin waste disposal studies are conducted at Stoneville and Mesilla Park. Packaging research is underway at Stoneville and Clemson. Lint cleaning studies are conducted at Stoneville, Clemson, Chickasha and Mesilla Park. Research on gin stands is carried on at Stoneville, Chickasha, and Mesilla Park. Equipment requirements for cottonseed drying, cleaning and storage are studied at Stoneville. The work at Chickasha, Oklahoma, was discontinued June 30, 1963. Research was cooperative with State Experiment Stations, Agricultural Marketing Service, Economic Research Service, industry, and individuals, as well as other Divisions in the Agricultural Research Service.

The Federal engineering effort devoted to research in this area totals 20.0 professional man-years. Of this number 2.6 is devoted to seed cotton handling and storage, 2.8 to seed cotton drying equipment, 2.5 to seed cotton cleaning, 1.8 to conveying equipment, 2.0 to gin stand, 5.0 to gin performance and cotton quality, 1.0 to lint cleaning, 1.8 to gin waste disposal, and 0.5 to program leadership.

A. SEED COTTON HANDLING AND STORAGE

1. Preliminary tests made at Stoneville in cooperation with the Cotton Harvesting Investigations and a farm implement manufacturer on compacting seed cotton as it was mechanically harvested to reduce the trailer space requirements did not appear practical. The damp and wet cotton when compacted showed grade reduction due to color loss and imbedded foreign matter. Tests at Chickasha showed that dry stripped cotton could be baled for storage either before or after cleaning without apparent quality damage. All lots in the test classed Low Middling Light Spot.

B. SEED COTTON DRYING

1. Automatic Drying System. Continuous operation of the Stoneville multi-path driers and their automatic control system showed the system capable of operating under commercial conditions. Sixty percent of the samples tested were within one percent and 93 percent of the samples were within one and one-half percent of the target moisture. To date experience has shown that for more precise control the drier operation should be governed by the moisture content of the incoming cotton and the moisture content of the fiber leaving the drier, to compensate for uncontrollable variables such as relative humidity. This is now being done by commercial instrument manufacturers.

At Clemson, for the third year, tests using 11 different drier combinations showed that about 81 percent of the total fiber moisture removal occurred during the first pass through a drier. Cottons harvested at eight percent and 10 percent lint moisture produced bales valued at $154.46 and $148.83, respectively, when both were dried to a level of six percent lint moisture for ginning. This difference was due primarily to the original moisture content of the cottons. Cottons harvested with lower seed cotton moisture gave higher turnout when all lots were brought to six percent lint moisture content at time of ginning. Only minor differences in fiber properties were noted as a result of the drying treatments used in this study.

2. Bench tests at Stoneville showed that residues from some commonly used insecticides and defoliants can cause errors in electronic fiber moisture measurements.

C. SEED COTTON CLEANING

1. Cleaning Recommendations. Tests on hand-picked cotton showed very little grade improvement after 13 cylinders of seed cotton cleaning. Machine-picked

cotton showed virtually no improvement beyond 19 cylinders of seed cotton cleaning when used in combination with a bur-and-stick machine. On the basis of these tests and other observations for machine-picked cotton, the Stoneville Ginning Laboratory recommends 12-14 cylinders of seed cotton cleaning together with a stick-and-green-leaf machine insofar as seed cotton cleaning machinery is concerned for old style plants and for 18-21 cylinders of cleaning, and a stick-and-green-leaf machine for plants having high-capacity gin stands.

For convenience, some gins have the feed control located in the overflow bins. If this arrangement is not properly adjusted it allows the seed cotton to recirculate through the seed cotton cleaning and drying machinery. Tests to illustrate what happens under such conditions were carried out at Stoneville. The test showed that when cotton is recirculated through the equipment, the quality deteriorates rapidly. An article was published presenting these data and making recommendations as to how this fiber damage may be prevented.

Tests were made at Clemson on a device to break up large masses of seed cotton coming from the feed control. Satisfactory lock separation was obtained but this treatment did not appear to improve the grade of the lint.

Grid bars placed in a screw conveyor trough showed some promise as a seed cotton cleaner. Preliminary tests indicate that it may be possible to utilize the seed cotton conveying system for seed cotton cleaning.

2. Studies of grass removal at Clemson showed that crab grass and crowfoot grass were more easily removed from cotton at stages before the seedhead opens. This stage occurs early in the season when grass content in the cotton is normally quite low. After the seedhead opens and before frost, seedheads adhere tenaciously to the fiber and are difficult to remove. Before frost, grass remaining in the lint after cleaning consists primarily of large segments while after frost the seedhead will shatter in the cleaning machinery. Scattered seedheads are less likely to contribute trash that cannot be removed by cleaning machinery.

3. Tests using experimental hard-lock separators showed that the grade and fiber quality could be improved by their use. Considerably more refinement is needed before the equipment will be practical for commercial use.

D. CONVEYING

1. Two types of wagon suction control valves were developed and tested at Chickasha. These valves worked quite well under laboratory conditions and will effect power savings of an estimated 1.5 cents per bale.

E. GIN STANDS

1. Results of tests made at Stoneville show that the quality of the fiber is quite acceptable when ginned on high-capacity saw gins. Several new principles of removing the lint from the seed are under investigation at Stoneville.

2. Roller Gins. Studies at Mesilla Park showed that increasing the pressure between the stationary knife and the ginning roll from 88 to 159 pounds per square inch increased the capacity of roller gins from 8.8 to 15.6 pounds of lint per inch of roll per hour. Further increase in pressure did not increase ginning capacity. There were no indications of fiber quality damage due to the increased pressure. Ginning roll and knife temperatures did increase with increased pressure and at the higher pressure were excessive and would decrease the life of the ginning roll.

Ginning flight-bar speeds of 750, 975, 1,200, and 1,425 strokes per minute were tested. Ginning capacity increased up to 1,200 strokes per minute but declined thereafter for the bar spacing and size of the unit tested. There were no adverse effects apparent on fiber quality as flight-bar speed was increased.

Ginning roll surface speeds of from 5,440 inches per minute to 8,407 inches per minute increased ginning capacity from 14.07 pounds of lint per inch of roll per hour to 16.95 pounds. Lint fiber quality was not apparently effected by the ginning roll speed. Ginning roll surface temperature and the ginning knife temperature increased as the ginning roll speed was increased.

Using three rates of feed, 18.1, 26.7, and 32.5 pounds per minute tests show that ginning capacity of a 24-inch flight bar gin is directly affected by the rate of feed within the test range. There were no adverse effects on fiber quality detected. The percentage of seed cotton carryover increased from a low of 34.5 percent to a high of 41.8 percent over the range tested.

Of the various principles of roller ginning investigated by Mesilla Park Laboratory personnel, the rotary knife method is the one being adopted by the gin machinery manufacturers.

3. Adjustment for Optimum Roller Gin Performance. Research at Mesilla Park showed that the gin roll surface temperature increased nearly linearly with increased pressure. At a roll speed of 100 r.p.m. the roll surface temperature was 45° F. above ambient when the pressure was 22 p.s.i. and it rose to 118° F. above ambient when the roll pressure was increased to 54 p.s.i. Roll surface temperature and roll-to-knife pressure were closely correlated, examples being +.83 at 40 r.p.m. and +.98 at 100 r.p.m. There was a sharp temperature gradient from the knife to roll contact area to the back edge of knife where it was fastened. Foll surface temperature followed knife temperature but was lower. Roll and knife temperatures were only slightly affected by roll speed. The increase in power required to turn the roll

was nearly linearly related to roll pressure. Doubling either the roll pressure or the roll speed doubled power needed to turn the roll. When the roll-to-knife pressure was adjusted to equal values at each end of the knife, the pressure was less towards the center due to bowing of the knife, knife rail and possibly the roll. The roll surface operating equilibrium temperature profile along the length of the knife had the same form as the roll-to-knife pressure profile.

At roll speeds of 100 r.p.m. and above, with pressures in excess of 70 p.s.i., roll surface temperature rose as high as 365° F. and some roll contact areas on the knife went above 400° F. At these high temperatures the roll covering material broke down rapidly. The strain gages, thermometers, and mounting cements also failed at the high temperature.

F. GIN PERFORMANCE AND COTTON QUALITY

1. Power Requirements and Efficiency. A commercial plant studied at Chickasha operated for the season at a gin stand utilization efficiency of 74.6 percent. Of the time the gin was not ginning cotton, 54 percent was due to some difficulty with the plant; 16 percent was due to changing trailers under the suction telescope; 15 percent was due to a stand being out of service; and 15 percent to idle operation.

Results of gin efficiency studies in the Southeast made by the Clemson Laboratory closely paralleled those at Chickasha. Additional factors affecting production rates noted by the Clemson Laboratory were non-uniform size lots of seed cotton and differences in the condition of the cotton delivered to the gin. Power consumption among bales was found to vary considerably due to disruptions in ginning rate.

Studies made by the Mesilla Park Laboratory showed that the per bale power cost: At 11 plants in California averaging 677 connected horsepower was 89 cents; at 7 plants in New Mexico averaging 392 horsepower was 81 cents; and at 12 plants in West Texas averaging 646 horsepower was $1.41. The power consumed per bale was: California, 47.68 kw.-hr.; New Mexico, 41.44 kw.-hr.; and West Texas 54.31 kw.-hr. Some of this variation is due to differences in electric rates. About one-third of the total power was used to unload and move seed cotton and about one-ninth was consumed in trash disposal and a similar amount for moving seed and lint.

The number of trash fans per gin averaged 2.8 in New Mexico, 5.0 in West Texas, and 5.7 in California. Per bale power costs for handling trash ranged from a low of 2 cents in one plant to a high of 21 cents at another.

Gin efficiency studies made at Stoneville showed that the pneumatic materials handling systems for high capacity plants require 77 percent of the total power when the gin is running idle as compared to 57 percent when the plant is ginning cotton.

The average ginning rate for the seven gins studied was 10 bales per hour with a connected load ranging from 456 to 917 horsepower or an average of 72 horsepower hours per bale.

Elapsed time indicators installed in the plants indicated a variation in operating efficiency ranging from 74 to 92 percent.

Power requirements will vary considerably among machines due to ginning rate. For gin stands and lint cleaners, power requirements vary exponentially with ginning rate. A linear relationship was noted for extractor feeders. The tests provided sufficient data to derive an expression relating the actual power requirements for fiber separation during the ginning process as a function of ginning rate as follows:

$$y = 0.243x^{1.6}$$

y = horsepower required for fiber separation
x = ginning rate, 100 lbs. per hr.

2. A fiber cleaner developed at Stoneville was subjected to operational tests. These tests showed where improvements in speed and efficiency might be made in the machine.

A procedure was worked out at Stoneville to reduce routine oven testing time from five hours to one hour. A formula was developed for use in calculating the moisture from the seed cotton weight loss after oven drying for one hour. The formula gives satisfactory results for seed cotton moisture of less than 11 percent.

A seed coat fragment test developed at Mesilla Park and used for routine evaluation at the Ginning Laboratories has been accepted and is being published as a tentative standard by the ASTM.

3. Tests at Stoneville showed that moisture content affects the breaking strength of individual fibers. Tests made under six conditions ranging from 3.7 to 15.3 percent moisture regain showed an increase in fiber breaking strength of .17 grams for each percentage point increase in fiber moisture content. The correlation coefficient was .97.

Tests at six relative humidity levels showed that mean fiber-seed separation force was virtually unaffected by changes in relative humidity in the 20 to 75 percent range. These tests which were made at Stoneville showed that a slight reduction in separation force was observed at 88 percent RH and a greater reduction at 92 percent. The number of fibers breaking rather than pulling off the seed ranged from 21 percent at the 20 percent RH level to only 2 percent at the 92 percent level. These data show that optimum conditions for separating fiber from seed with minimum fiber breakage are at high fiber and seed moisture conditions.

Instruments are being modified at Mesilla Park to measure fiber-seed strength attachment. Preliminary measurements which have been made show that strength of attachment is correlated with ginning capacity and fiber qualities.

4. Effect of Cultural and Harvesting Practices. At Stoneville, in cooperation with the Delta Branch Experiment Station, 10 commercial varieties were compared from the standpoint of gin cleaning in terms of foreign matter content and lint grade. Rex Smooth Leaf gave the highest grade, followed by Stoneville 7A; Stoneville 213; and Delta Pine Smooth Leaf. The other six varieties ranged downward to almost a full grade below the Rex Smooth Leaf.

The effect of picker lubricating oils was studied at Stoneville in cooperation with the Cotton Mechanization Project. These tests showed that spindle picker lubricating oil caused a slight adverse effect on the reflectance of the lint, gave increased picker and card waste during spinning and an indication of lower yarn strength. Fiber properties did not appear to be affected.

Tests comparing the quality of cotton mechanically harvested from clean and grassy fields showed that the lint cleaner is most effective in removing grass from lint. This test at Stoneville, in cooperation with the Cotton Mechanization project, showed that 12 of 15 samples from a grassy field were reduced in grade because of grass, while after lint cleaning the cottons harvested from clean and grassy plots were of comparable quality.

Gleaning cotton from the ground has come into widespread use in recent years. Because of success in other areas, it was necessary to investigate the possibility of using these ground reclaimers in the Mid-South area in order to answer questions being asked by farmers. This work in cooperation with the Cotton Harvesting Section at Stoneville showed that even though this material is lower in grade, ground-loss cotton usually sells for only a few cents per pound less than machine-picked cotton, depending on the length of time the cotton remains on the ground and the weather conditions prior to recovery.

Information obtained by personal interviews with 16 owners of mechanical cotton gleaners indicated the following:

> Based on a 500-pound bale of "recovered" cotton with a lint price of 25.8 cents per pound, each bale will bring about $129. At an average machine and labor cost of 8.02 cents per pound of lint recovered, or $40.10 per bale plus a ginning cost of $8.18 per bale above seed credit, the farmer could expect a net return of about $80.72 per bale. No charges for land rent, management, taxes, and other overhead costs have been removed from this net figure since these all differ by individual farms and operators. On cotton fields yielding a bale of recovered cotton every eight acres, the returns per acre would amount to approximately $10.09. These figures are based on the machine operating twenty 8-hour days, or approximately 160 hours per year.

Defoliation-timing study experiments using five varieties and strains, machine-picked at two stages of maturity and ginned in three replications at Stoneville on a conventional ginning setup as recommended for machine-picked cotton were carried out. The results show that based on lint foreign matter content and grade, the early defoliation and harvest is better than the late defoliation treatment. Other aspects of the analysis are given in reports by cooperative agencies.

Work was done this year at Stoneville in cooperation with the Cotton Harvesting Section to determine the extent and cause of variations in the distribution of foreign matter in a mechanical picker basket and its possible relation to variations in lint grade classification and lint foreign matter content. The tests showed that there was a wide range in the foreign matter content of the cotton as represented by samples taken at 18-, 36-, and 54-inch depths in the mechanical picker basket. Although there were some differences in wagon sample foreign matter content between composited and uncomposited lots, the equalizing effects of processing the cotton through the cleaning system of the gin provided almost identical average foreign matter distribution in the cotton at the feeder apron. This resulted in identical lint grade and very closely comparable lint foreign matter content. In final analysis, this one year's data showed that the compositing or stirring of the machine-picked cotton prior to cleaning and ginning offered no advantages over the uncomposited cotton.

One year's data on a study of topping cotton at Stoneville showed that the highest foreign matter content and lowest grade index value of 95.0 were associated with the control or untopped cotton. Early topping resulted in a grade value of 97.0 as compared to 99.0 for late topping, and a value of 100.0 for the samples representing the cotton trimmed periodically through the fruiting stages.

Tests of three levels of defoliation--none, normal, and premature--carried on at the Mesilla Park Laboratory gave micronaire readings of 3.6, 3.7, and 3.4 respectively. Among three sets of variables--defoliation, moisture contents, and cleaning machinery--the greatest effects on cotton qualities and spinning performance were caused by the defoliation treatments. The slightly, but significantly lower, micronaire readings, resulting from premature defoliation, caused numerous significant differences in measurement, all of which indicated lower quality or poorer performance.

A study at Chickasha, Oklahoma, covering a period of three years showed the effects of including various amounts of lint from damaged or immature locks and bolls in the bale along with mature lint, such as sometimes occurs due to indiscriminate harvesting by mechanical strippers. Increases in immature lint content have consistently resulted in undesirable effects on yarn appearance, yarn strength, fiber coarseness, lint color and brightness, unit lint value, lint waste content, manufacturing waste, and fiber neps.

Four years of comparing picker and stripper harvesting of irrigated cotton have been completed. The cotton for these comparisons was grown at the Altus Irrigation Experiment Station, and ginned at the Chickasha Ginning Laboratory. In two years of high yields (1-1/2 to 1-3/4 bales per acre) once-over stripping of Acala 44 returned 17 to 20 dollars per acre more than double picking, and 25 to 33 dollars more than picking followed by stripper-scrapping. These results are because of the higher ginned lint yields and lower harvesting fees, and notwithstanding the lower grades, shorter staple, and higher ginning charges usually associated with once-over stripping. In years of low yields (1/2 to 3/4 bales per acre), picking followed by stripper-scrapping has averaged three dollars per acre more profitable than once-over stripping of Acala or Austin.

Two years of comparing various methods of preparing irrigated cotton plants for stripping and of dates of stripping indicate that defoliation and/or desiccation to permit before-frost harvesting entails the risk of harvesting large quantities of green bolls. Acre returns may be greatly reduced because of the loss of lint contained in the green bolls; this loss is, to a great extent, avoided by waiting until after frost to harvest. Drying and green boll removal requirements in the gin are much greater for before-frost stripping.

G. LINT CLEANING

1. Work was carried out at Stoneville to: (1) Determine the effect of rate of feed on the efficiency of a lint cleaner, and (2) determine the effect of lint moisture on trash removal and fiber length distribution. One year's data show that the percentage of trash removed increases as the rate of feed increases over a range of from 17 to 29 pounds of lint per minute. Over a range of from 3.8 to 7.0 percent lint moisture, total trash removed by the lint cleaner parallels the change in initial trash content of the lint. This indicates that the efficiency of the lint cleaner is independent, within the ranges studied, of moisture content of the ginned lint.

H. GIN WASTE DISPOSAL

1. Work was initiated during 1962-63 at both Mesilla Park and Stoneville to develop a more efficient means of collecting fly lint and dust exhausting from condensers in the ginning system. A pilot model exhaust system was constructed and preliminary performance data obtained for three screen filter media. Data was also obtained for these filter media when coated with thicknesses of fine lint fiber. Additional bolting screen filters of a very fine mesh are now under test. Inclined automatic cleaning filter units employing fine mesh bolting screens have been designed and constructed for tests.

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AREA NO. 7: STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Problem. The magnitude of the crop and machinery storage problem is evidenced by the vast quantities of crops and other materials handled and stored on the farm. Annually on the farm: (1) Five billion bushels of corn, wheat, and other grains are harvested and stored, of which nearly one billion is carried over from the preceding year; (2) 185 million tons of hay and silage are processed and stored; (3) nearly three million bushels of apples and pears and 13.5 million hundred-weight of potatoes and sweet potatoes are held for home consumption; (4) other large quantities of fruits and vegetables are held for temporary storage pending marketing; and (5) large amounts of fertilizers and feeds are purchased and held in storage pending use. An aggregate total of more than seven million tractors, combines, corn pickers, and other complicated farm machines would retain their efficiency longer and operate more reliably if stored under shelter and tuned up in farm shops.

Relatively little research on farm storage structures has been done in recent years--even though there have been many new developments that affect storage and handling problems. For example the trends toward large diameter silos and different silages call for new data on pressures exerted against the silo structure. Among these new developments may be mentioned:

Changes in harvesting methods such as picker-shelling of high moisture corn, wafering of forage, combine harvesting of potatoes, and mechanical harvesting of apples and other fruits and vegetables.

Need for integrating feed storage into complete feeding systems; for example, large diameter silos with feed bunks, paved feeding area, and a conveyor system.

Development of electrically operated and controlled mixing and metering systems.

Increase in number of rural non-farm families outside of villages that raise some of their own fruits and vegetables.

The cold war situation and potential fallout hazard that emphasizes value of locally available feed and food supplies, and introduces requirements for new designs and arrangements for the storage and operating facilities.

There is also urgent need to develop engineering design criteria for constructing and equipping plant growth chambers that will reliably provide and maintain desired thermal, lighting, and other environments over a wide range of experimental conditions. Recent experience of plant and other scientists concerned with use of plant growth chambers indicates a general inability to closely maintain desired environmental conditions and a lack of means for measuring conditions maintained in these units. Design criteria for automatically maintaining scheduled environments are needed also for greenhouses and other production type plant growth structures.

USDA PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures.

A. Crop Storage Structures (silos and bins). Research is cooperative with Animal Husbandry Research Division, ARS; with Cooperative Regional Research Project NE-13, "Determination of the Basic Job Requirement of Machinery for Harvesting and Storage of Grass Silage", at Beltsville, Md.; and with the Agricultural Experiment Stations at Athens, Ga., East Lansing, Mich., and Ames, Iowa.

B. Plant Growth Structures (environmental chambers and greenhouses). Research at Beltsville, Md., is cooperative with Crops Research Division, ARS.

C. Plan Development. Typical plans for crop structures and related equipment are developed at Beltsville in cooperation with the regional committees representing all State Experiment Stations and Extension Services.

The Federal effort in this Research Area totals 4.8 professional man-years. Of this number 3.2 are devoted to crop storage structures; 1.2 to plant growth structures; 0.1 to plan development; and 0.3 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Crop Storage Structures

1. Silo design criteria. Tests on two concrete silos at Beltsville showed that the walls of old silos could be restored and further acid damage prevented economically by lining with aluminum sheets. A combination of glue and blind riveting appears to be a satisfactory application method. Plain lap seams sealed better than handmade lock seams. After two years, the lining showed some acid etching and scattered punctures from silage forks. Small amounts of spoilage that occurred along some unsealed seams the first year were eliminated by resealing them with the neoprene-base glue used to apply the sheets.

Radioisotope determination of density at Beltsville, Md., continued with corn silage, rather than with grass silage, as in 1961. The point at which the silage was delivered in the silo was off center to determine if a dense pillar would be formed. At the point of delivery, as measured by gamma energy, the silage density was 16% more than the density at the opposite side of the silo. This change occurred at a very uniform rate. Potential sensitivity of the method was indicated by its detection of an increase in density of 3% due to tramping the silage. However, instrument stability is still troublesome, and at the greatest densities measured, 45 p.c.f. (pounds per cubic foot), possible error due to background radiation is large.

At Athens, Ga., work was started on measuring the gaseous transfer rate of silo staves. The oxygen transfer rate has been measured on a small number of concrete staves and additional work is planned for measuring the air and carbon dioxide transfer rates through many concrete staves and possibly other materials.

At East Lansing, Mich., studies of corn silage pressures in large diameter upright silos were continued. Pressures in a 30 x 60 ft. tower silo were measured for the third year by means of suspended panels. With poor silage distribution in 1962, maximum wall pressures were 630 p.s.f. (pounds per square foot) horizontal, and 300 p.s.f. vertical. These pressures were substantially greater than those of 1961 (400 and 150 p.s.f.) and occurred with nearly identical crop conditions and distribution. In 1960, with more uniform distribution, the pressures were 700 and 120 p.s.f. In 1961 and 1962 with poor distribution, horizontal pressures were less than in 1960 with uniform distribution. The position of the suspended panels was directly opposite the point of greatest silage depth, and pressures at that point may be much greater than those where the depth is uniform. Average moisture content of the silage has been nearly the same for the three years; however, distribution of the silage having different moisture contents may have contributed to the wide variation in pressures. Data such as these are essential for engineers to predict pressures developing in silos.

2. Heavily wilted silage storage. At Beltsville, Md., 2 years' tests of storing heavily wilted silage in two 10 x 40 ft. tile stave silos showed that high dry matter alfalfa (40.4 - 40.8% D.M.) can be safely stored in conventional silos. Total losses ranged from 4.6 to 11.8%. These comparatively small losses indicated that a strip of 14-pound asphalt felt or plastic is as effective as gaskets or calking compound in sealing the silo doors. The only apparent requirement is that the felt or plastic be kept in contact with the silo wall. The variation in the above losses also shows less spoilage occurred when plastic covers on the top of the

silage were weighted with a foot or more of green forage, which was high in the center to maintain a tight seal between the plastic and the silo wall. Average temperatures in the 4 trials ranged from 89° to 93°F., with peak temperatures of 94°, 102°, 108°, and 112°F. These temperatures indicate good air exclusion. Feeding trials indicated the feed value of the silage was equal or superior to good quality hay.

3. Bunker silo tests. At Beltsville, Md., a bunker silo was loaded to a depth of only 3 feet with orchard grass wilted to 45% moisture. The silo was thoroughly sealed by lining the plank walls with plastic film which was folded in after tramping the edges and covered with a separate piece of plastic. The cover was then weighted with a 3-inch layer of sawdust. Although the amount of plastic used was twice that for a cover alone, loss by spoilage was insignificant. Temperatures were higher close to the surface, but none were excessively high. As an indication of microbiological activity, this may be significant nutritionally. The average density of the stored dry matter was 13.6 p.c.f. Wall pressures were obtained by means of suspended panels, and yielded these pertinent values per foot length of wall 3 feet high--lateral force: maximum 240 lb., settled 150 lb.; overturning moment: maximum 275 ft. lb., settled 150 ft. lb. These data contribute to knowledge of requirements for designing bunker silos to economically store these silages.

Another bunker silo was filled to a depth of 8 feet with corn silage. Pressures on the side wall were measured during filling and settling. The maximum measured horizontal pressure was 170 p.s.f. and values per foot length of wall were--lateral force: maximum 890 lb., settled 600 lb.; overturning moment: maximum 2850 ft. lb., settled 1600 ft. lb.

4. Coastal Bermuda grass silage. At Athens, Ga., work was started during the year on a basic study of factors influencing the storage quality of Coastal Bermuda grass silage. In the laboratory, 588 one-half gallon glass jars were filled with this silage. Moisture content, density, level of corn additive, stage of maturity, exposure before sealing, kind and level of additive, air infiltration rate, and length of time of air infiltration were observed. All treatments were replicated and the results analyzed statistically. Dry matter loss and pH were determined for all samples and a chemical analysis made of 16 composite samples. Silage with 40 and 50% dry matter showed superior quality to silage with 30% dry matter. The optimum level of corn additive was about 100 lbs./ton although improvements were made by the addition of more corn. Silage quality was improved with a 24-hour delay in sealing the jars when compared to jars sealed immediately after filling. Quality also improved with stage of growth as the stage increased from three weeks to seven weeks. These results from both the exposure time and stage of growth are contrary to previous reports. The effects of air infiltration rates were significant but not as pronounced as originally expected. Additional studies of this type will be needed to fully determine and evaluate the factors influencing storage quality of Coastal Bermuda grass silage.

5. Hay wafer storage. At Beltsville, Md., storage of hay wafers was studied in a variety of plain and forced air bins. Storage densities up to 22.8 p.c.f. (20 p.c.f. dry matter) occurred with well consolidated alfalfa wafers, but with poor crop and wafering conditions this was reduced to as low as 13.7 p.c.f. (12 p.c.f. D.M.). Safe storage moisture content for alfalfa wafers under Beltsville conditions was 14%.

It was not possible to control the movement of these wafers from storages with bottom doors or trenches. Difficulties experienced indicate the need for additional study to determine the design requirements for bins that can be unloaded with mechanical equipment.

6. High moisture shelled corn. At Ames, Iowa, studies were undertaken on the effects of airtightness, moisture content, and initial infestation of microflora on the storage process of high moisture shelled corn. Six of the eight 200-bushel airtight storage tanks were filled with 33% moisture shelled corn. The other two with 29% moisture shelled corn. The oxygen in the tanks was depleted within 6 to 8 hours after the tanks were sealed. The carbon dioxide concentration increased to about 97% in about 70 hours accompanied by a 5 to 10°F. temperature rise. The 33% moisture corn produced about 11 grams of carbon dioxide per kilogram of dry matter in the tanks in 12 days. No further production was detected except that produced when measured air "leaks" were introduced. This initial production was almost all anaerobic and it was estimated that this activity resulted in about a 1% loss of dry matter. A 2.5 to 3.0 percent dry matter loss was measured in all tanks over the storage period. The maximum measured "leak" of 50 cubic feet of air per day for 16 days in two periods of 8 days each did not appear to have created any spoilage. It was estimated the tanks contained about 150 cubic feet of gas. The oxygen introduced was converted to carbon dioxide within a few hours after it was introduced. The carbon dioxide concentration approached about 20% with "leak". The no leak tanks also approached 20% carbon dioxide concentration at the time of unloading.

B. Plant Growth Structures

1. Environmental chambers. At Beltsville, Md., studies to date have been concerned principally with improving existing facilities. Equipment and instrumentation for measuring and recording data on the various thermal factors (temperatures, air flows, relative humidities, etc.) involved are being acquired or developed.

Several small chambers, needed for plant physiology research, were used experimentally to test means of maintaining uniform ambient temperatures

through a range of levels of light intensity. The chambers were inside an air-conditioned room. Small exhaust fans were installed in the chambers and set to blend the warmer chamber air with incoming cool room air at the room ceiling. The installations are operating successfully and a report of design details is being prepared.

A means for protecting the temperature controls of a "hot room" for treating virus infected plants was developed and tested and found to perform satisfactorily. Initially the controls had been installed inside the hot room where the high temperature and humidity caused rapid deterioration. Redesign of the system and placement of the controls in an electrically warmed, insulated box that provided a uniform temperature solved the problem.

Several experimental modifications were made on a commercial growth chamber at Beltsville, Md., during the past year. The growing area was divided lengthwise to allow testing of two types of lamps. Recording instruments were placed on the chamber to measure compressor pressure, temperature, and humidity of the growing area, intensity, quality, and operating time of the fluorescent lamps, and air velocity. Continuous testing of plant responses to light quality has been carried on since July 1962. All tests compared "special phosphor" fluorescent lamps to "cool white" fluorescent lamps. Some also had incandescent light supplementing each quality fluorescent light. Pinto beans were slightly heavier under "cool white" light than under "special phosphor", both with and without incandescent light. Incandescent light caused the beans to elongate more, but made no difference in weight. Beans under "cool white" light were longer than those under "special phosphor" without incandescent light, but were shorter when "special phosphor" was supplemented with incandescent light. Marigolds produced more blooms under "cool white" light in the same test. No appreciable difference was found with oats and African violets. All plants under both sources of light grew well. Problems of overheating of lamp ballasts during the hot summer and condensation of refrigerant during the coldest winter nights were studied and successful corrections developed.

Several monitoring instruments have been developed and successfully tested for obtaining a record of conditions within environmental chambers of different types in different types of operations. Monitored conditions included humidity, temperature, air flow, refrigeration equipment operation, and other quantities. The information obtained will serve as design criteria for these chambers.

2. Greenhouses. At Beltsville, Md., a temperature-humidity recorder was placed in an air-conditioned potato greenhouse to obtain information that could be applied to air conditioning of other greenhouses. By comparing the data obtained from the air-conditioned potato greenhouse and from an existing sugar cane greenhouse, it was determined that humidifying equipment was not necessary for normal sugar cane growth in an air-conditioned greenhouse.

Models of three small, low-cost, plastic covered greenhouses for home gardeners were developed, tested, and evaluated. The final design is economical, easily built, strong, and durable.

C. Plan Development

Four typical plans for crop storage, and plant growth structures and equipment were developed during the year at Beltsville, Md., for inclusion in the Cooperative Farm Building Plan Exchange. They are: a small (8'-6" x 12'-0" x 7'-0" high at the ridge), plastic covering over plywood frame, greenhouse for home gardeners; a 5'-4" x 7'-8" x 7'-8" high, plastic covered, wood-frame, greenhouse--coldframe; a lightweight, 36' long trailer for 30'-40' length irrigation pipe sections; and a small, dual-purpose, fruit and vegetable storage cellar that also serves as a fallout shelter for six persons.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

A. Crop Storage Structures

Hendrix, A. T. and McCalmont, J. R. 1962. Harvesting, storing and feeding silage. Presented before Inter-European Symposium on Modern Construction Techniques in Agriculture, Jonkoping, Sweden, June 15.

James, P. E., Wilkins, D. E., and Menear, J. R. 1962. Silage density: as measured by gamma energy attentuation, report no. I. Presented at North Atlantic Section, ASAE, Morgantown, West Virginia, August 19-22.

Holdren. R. D. and Menear, J. R. 1962. Wafering research progress at Beltsville. Prepared for Massey-Ferguson Seminar, Chicago, Illinois, December 10-11.

B. Plant Growth Structures

Bailey, W. A. 1962. High temperature growth chambers using natural light. Presented at Symposium on Engineering Aspects of Environment Control for Plant Growth, Melbourne, Australia, September 1-5.

C. Plan Development

Farm fallout shelter and storage. 1962. (Exchange Plan No. 5934). USDA Misc. Pub. No. 910, November.

AREA NO. 8: RURAL DWELLINGS

Problem. The 1960 Census of Housing indicates that although about 500,000 new farmhouses were built between 1950 and 1960, rural housing as a whole continues to be older than and inferior to urban housing in condition and value of buildings and in availability of plumbing, heating, and labor-saving equipment. The percentage of farmhouses with flush toilets increased from 27 percent to 62 percent between 1950 and 1960, and the percentage without piped water supply was reduced from 55 percent to 23 percent in the same period. However, the improvement in these percentages was due partly to change in the Census definition of a farm which removed from the "farmhouse" classification of the Census some 2 million houses on small acreages or on land that had been consolidated into larger holdings. Many of these homes must now be included in the rural "non-farm" category. But whether classified as "farm" or "non-farm" large numbers of houses outside of cities and towns remain without the conveniences and comfort features of typical urban homes.

Housing costs are still a major obstacle for farm families that wish to make improvements for themselves or to furnish better housing to attract and hold qualified and reliable tenants or full-time or migratory workers. Costs are also a problem for the rural non-farm family. Continuing research is needed on ways to reduce costs through better use of space and improved application of old and new materials. There is need for simpler, really low-cost designs that provide only the minimum essentials of good housing; and the "shell house" should be studied for further improvement of its first stage and to make completion easier.

On the other hand, the stepped-up Farmers Home Administration program of rural housing loans needs research support to provide designs that will meet modern housing standards at moderate cost and be sound and desirable security for 30-year government loans. The design and equipment of houses for improved control of temperature, air movement and noise, and economy of operation and maintenance also need further research.

With the rapid increase of the non-farm population in rural areas outside of villages, including many elderly and retired people, more attention should be given to their housing. People who have vegetable gardens and garden equipment to store, and who live on small acreages, drawing water from wells and using septic tank sewage disposal systems, have housing problems very like those of farmers, and the housing abilities of the Department could be very useful to them. Engineering research and design of equipment for the elderly is also needed.

In view of the continuing "cold war", consideration should be given to types of both farm and non-farm houses that would provide shelter from fallout if an emergency should develop. Basements could provide fallout shelter at small additional cost for families that do not have to care for livestock. Development of types of houses having the basement as an attractive area for full-time use is a challenging problem and would be a valuable achievement. On livestock farms, the family fallout shelter probably should be in the main livestock building.

USDA PROGRAM

The U. S. Department of Agriculture is conducting a continuing program of housing research involving engineers and architects.

Five experimental houses at the Agricultural Research Center are under continuing evaluation of design, temperature control features and occupant reaction, in cooperation with Clothing and Housing Research Division, ARS. Construction methods and materials and temperature, air motion and noise control are studied at Beltsville, Md.; at State College, Miss.; and at Athens, Ga.; in cooperation with the Mississippi and Georgia Stations, respectively. Architectural design and preparation of farmhouse plans for the Cooperative Farm Building Plan Exchange and related publications are carried on at Beltsville in cooperation with Clothing and Housing Research Division, ARS, and the Federal Extension Service. The State Agricultural Colleges cooperate through Regional Committees in establishing housing requirements and making the plans available to the public. Farmers Home Administration consults on requirements and makes plans available to its clients.

Federal effort in this Research Area totals 5.8 professional man-years. Of this number, 1.2 were devoted to design criteria for comfort, health and safety; 1.4 to studies of materials and construction; 0.9 to systems for environmental control; 1.9 to development and preparation of improved farmhouse designs; and 0.4 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Design Criteria for Comfort, Health, and Safety

1. Thermal and sound control. At Athens, Ga., in cooperation with the State Station, preliminary preparations were made for a study of conventional and new interior window treatments (drapes, etc.) and soft floor coverings in an effort to reduce heat loss in winter and heat gain in summer, reduce drafts and improve comfort. Environmental factors in the study include dry bulb temperature, radiation, air motion and noise. Different types of windows and fabrics will be studied. Fabrication of the heat transfer equipment needed for the study is virtually complete. A data-logger with IBM punch card output has been constructed so that the data from 24 sensing elements can be recorded and analyzed with a minimum of labor.

Also at Athens, studies are underway in occupied houses to determine sound levels and range of sound frequencies. These data will be analyzed and the sound levels and frequencies reproduced in a reverberation room to study the effects of various window and floor treatments. Equipment has been obtained for this study. The reverberation room has been designed and construction will be started soon.

Manuscript for an agriculture handbook on farmhouse design and equipment for summer comfort was completed.

2. Farmhousing laboratory. A new steel building, 32' x 48' in size, has been completed at Athens and is being equipped as a laboratory for making heat transfer, sound, and other environmental studies applicable to farmhousing.

3. Planning aids. A series of short publications to serve as planning aids is being prepared at Beltsville, Md., and Athens, Ga. These aids will give information, mostly in graphic form, on some of the most important problems confronting families who plan to build or remodel a house. They will be especially valuable as inexpensive handouts for use by the Farmers Home Administration and the Extension Service. The format has been approved and two publications, prepared jointly with Clothing and Housing Research Division, are about complete. Seven additional jointly-prepared aids are planned. Fourteen aids are planned by the Agricultural Engineering Research Division and work has been started on several.

B. Materials and Construction

1. Hyperbolic paraboloid shapes. At Beltsville, Md., preliminary investigation of models of basic house framing using hyperbolic paraboloid shapes indicated that, although such framing systems can be made from less material than conventional, the shape does not adapt easily to good interior plans, the fabrication may be expensive, and the appearance is too unconventional for wide acceptance.

2. Low-cost construction methods. At Beltsville, preliminary investigations on pressure treated pole framing and improved floor designs indicate that these are logical items for fruitful research aimed at lower cost house construction.

3. Foundations for expansive clay soils. At State College, Miss., cooperative work progressed on the movement of expansive clays and design of light foundations that retain position in such clays. This work was initiated by the Mississippi State College and joined during the year by USDA. Readings were made on elevation changes of variable depth plates and on test foundations. Plans were developed for installation of pier testing experiments.

C. Systems for Environmental Control

At Athens, Ga., plans are being completed for a study to determine the optimum arrangement of attic fans in relation to placement of roof or ceiling insulation for reducing summertime temperatures economically in rural homes. The work will be done in occupied homes with fans controlled by thermostats. Temperatures will be recorded automatically. More desirable temperature control should be attained by this study for use by those who cannot afford mechanical air conditioning or who prefer natural air ventilation.

At Beltsville, Md., a bedroom addition to an expansible house was completed and studies initiated to determine the climatic response, temperature distribution and infiltration of air resulting from the use of different construction and heat distribution methods as compared with the SCR brick walls and heating duct system in the basic unit. Occupant reaction as well as engineering data will be obtained. Information to date indicates that infiltration was about the same in the basic unit and the addition; only 1.1 air changes per hour were recorded at a 10-mile per hour wind velocity, thus indicating relatively tight construction. Similar infiltration tests for the other four houses are planned for next year.

Also at Beltsville, manuscript for Farmers' Bulletin 1889, "Fireplaces and Chimneys", was completely revised to bring it up-to-date. New ideas incorporated in the bulletin will give designers and builders proper information on this phase of house construction.

D. Farmhouse Design Development

Seven farmhouse plans released between April 1, 1962 and March 31, 1963 were designed for a wide range of economic and family needs and to meet specific requests of the Regional Plan Exchange Committees and the Farmers Home Administration. The plans include one for a two-bedroom house with liberal space allowances, two for three-bedroom houses of moderate size, two for four-bedroom houses (one of moderate size with basement and one large size without basement), and two for five-bedroom houses (both with liberal space allowances and with basements). Two additional three-bedroom plans are in the pencil stage of preparation, one a large house and the other with limited space allowances. A fallout shelter for construction in the basement of a home is also being designed. Five of the nine plans are within the 1400 square foot general limitation of Farmers Home Administration. Those with limited space allowances are designed for moderate cost of construction at a sacrifice of space. One design utilizes panels on pole framing so that much of the work can be done inside another building during inclement weather prior to actual erection. Low cost construction and minimum space are currently being emphasized.

Study plans and suggestions on apartment designs for the elderly were prepared for the Federal Public Housing Authority. Research findings on space requirements and arrangements were incorporated in the plans.

Eighty state plans for houses in the Southeastern region were reviewed for size, arrangement, general space allowances and desirable and undesirable features. This information was furnished to the Farmers Home Administration to help clients select suitable plans where those in the Plan Exchange do not meet their requirements or desires.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

A. Design Criteria for Comfort, Health, and Safety

Thompson, H. J., Biggs, A. A., and Simons, J. W. 1962. Changes of moisture and temperature under a concrete slab floor in an expansible farmhouse. USDA ARS Series 42-64.

B. Materials and Construction

Teter, N. C. and Newman, J. O. 1963. Minimum structural standards for rural housing. Presented to Southern Association of Agricultural Workers, Memphis, Tennessee, February 4.

C. Systems for Environmental Control

None

D. Farmhouse Design Development

Two bedroom farmhouse with carport. 1962. (Exchange Plan No. 7156). USDA Misc. Pub. No. 897, March.

Three bedroom farmhouse - slab-on-grade, frame construction. 1962. (Exchange Plan No. 7150). USDA Misc. Pub. No. 912, September.

Three bedroom farmhouse - masonry, slab-on-grade. 1962. (Exchange Plan No. 7141). USDA Misc. Pub. No. 914, November.

One bedroom farmhouse - slab-on-grade, frame construction. 1962. (Exchange Plan No. 7154). USDA Misc. Pub. No. 915, December.

Two bedroom farmhouse - masonry construction. 1962. (Exchange Plan No. 7155). USDA Misc. Pub. No. 916, December.

Three bedroom farmhouse - masonry, with basement. 1962. (Exchange Plan No. 7139). USDA Misc. Pub. No. 917, December.

Cabin-frame, slab-on-grade construction. 1963. (Exchange Plan No. 5928). USDA Misc. Pub. No. 924, March.

AREA NO. 9: LIVESTOCK ENGINEERING (EXCEPT ELECTRICAL)

Problem. The American farmer has about $14 billion invested in service buildings and related structural equipment, over half of it for livestock facilities. Maintenance and new construction amount to another $1.2 billion annually, again mostly for livestock facilities.

Economic conditions are forcing changes in the pattern of livestock production. Producers are trending toward fewer, larger and more specialized enterprises and toward "confinement" types of facilities in their effort to reduce production costs and improve product quality. These trends are demanding more basic knowledge on the effects of environment on the health, growth, production and fertility of livestock; on structures and related equipment for maintaining optimum environments; and on methods, structures and equipment for more efficient handling and feeding. The continuing threat of nuclear warfare demands consideration of types of buildings that could provide protection from fallout for livestock and their feeds, and provide facilities for operation during periods of emergency. (Fallout protection work reported in Area 10).

Much more needs to be learned in the laboratory on the relationships between livestock environment and disease transmission, feed conversion rates, and growth and production in order to determine optimum environments. Structures and equipment for economically providing these optimum environments under practical conditions need to be developed and field tested. Closely associated with the environment are flies and other insects, as well as parasites and diseases, that sap the vitality of animals and reduce their productivity. Pesticide residues in animal products are causing much concern. Information is needed on means for keeping these residues from adversely effecting the animals or their products.

Labor also is an important element in overall production costs, and if only family labor is available, the labor requirement limits the size of enterprise. How to adapt existing buildings and other facilities for more efficient production, as herds and flocks are increased in size, or as farms are consolidated, is a major problem area. Cost of replacement or major improvement of existing buildings that are not suited to modern production methods are serious obstacles. Principles, examples and techniques for planning more efficient operations are needed both by farmers doing their own engineering and by those on whom farmers depend for advice.

Many types of structural and handling equipment such as feed bunks, self-feeding silos, and feeding floors, are important to a livestock production enterprise. Adaptations and improvements to keep design of such equipment abreast of current production practices and buildings are essential to the producer.

USDA PROGRAM

This is a continuing program involving engineers and architects conducting basic laboratory investigations, application of laboratory results to a production basis, and development of typical plans for livestock structures. The work is in cooperation with the AH, ADP, and ENT Divisions of ARS, USDA, and State Agricultural Experiment Stations, and contributes to Cooperative Regional Projects NC-23, "Farm Structures to Meet Environmental Requirements of Dairy Cattle, Swine, and Poultry", S-49, "Genetic Methods of Improving Dairy Cattle for the South", and NE-8, "Essentials of Poultry Housing for the Northeast". Plan development work is cooperative with all the State Agricultural Experiment Stations and Extension Services.

A. Dairy Cattle Engineering

Dairy cattle environmental and bio-engineering studies are conducted in a climatic laboratory at Columbia, Mo., in cooperation with the Dairy Husbandry and Agricultural Engineering Departments of the Missouri Station. AH, ARS, serves in an advisory capacity. Field studies in a hot humid region are conducted at Tifton, Ga., with the Georgia Coastal Plain Experiment Station and AH, ARS, cooperating. The influences of building arrangement, equipment, and chore routines on the amount and drudgery of dairy chores and means of improving these factors are studied in cooperation with the California Agricultural Experiment Station. Typical plans for dairy structures are developed at Beltsville as part of the Cooperative Farm Building Plan Exchange.

B. Beef Cattle Engineering

Beef cattle structures and equipment research for hot, dry climates is conducted in cooperation with the California Agricultural Experiment Station at the Imperial Valley Field Station, El Centro. Related studies for a warm humid climate are in cooperation with the Missouri Agricultural Experiment Station at Columbia, and with AH, ARS. Typical plans for beef structures are developed at Beltsville.

D. Poultry Engineering

Poultry house environmental design criteria are investigated in controlled-temperature laboratory studies at Beltsville, Md., in cooperation with AH, ARS. Field studies on relation of housing structures to poultry disease are conducted in Mississippi in cooperation with the State Experiment Station and AH, ARS. Environmental influences on health and housing are to be investigated in new laboratories at Athens, Ga., and State College, Miss., in cooperation with AH and ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minn., a study of the role of environment in the prevention and control of chronic respiratory disease in turkeys is underway in cooperation with the Minnesota Station. Typical plans for poultry structures are developed at Beltsville.

E. Livestock Shades and Shelters

Shades for sheltering livestock are being studied at Tifton, Ga., in cooperation with the Georgia Station.

F. Sky Radiosity Studies

Studies of sky radiosity have begun at Davis, Calif., and at Columbia, Mo., in cooperation with the respective Experiment Stations.

G. Reducing Pesticide Residues in Animal Products

Reduction of pesticide residues in animal products, with beef cattle receiving major attention, is studied at Kerrville, Texas, in cooperation with ENT and ADP, ARS, and the Texas Agricultural Experiment Station.

Federal research effort in this area totals 9.1 professional man years. Of this number 2.2 is devoted to dairy; 0.3 to beef; 1.3 to swine; 3.2 to poultry; 0.1 to shades and shelters; 0.2 to sky radiosity studies; 1.0 to reducing pesticide residues in animal products; and 0.8 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Dairy Cattle Engineering

1. Increasing efficiency of operations. At Davis, Calif., work was continued in cooperation with the Experiment Station on a study of dairy layouts having herringbone milking rooms. As herringbone milking rooms were constructed and became available for study with the large-scale dairy installations, they have been studied to determine their effectiveness as a means of reducing the labor requirements in these large installations. As a result of this work, plans for pie-shape layouts with herringbone milking rooms have been developed.

Also in cooperation with the Experiment Station at Davis, work has continued on analysis of a large volume of time and travel data that have been recorded on the large-scale dairy farmsteads. This material has been used as the basis for several publications and is now being worked up into a consolidated form to present the principles of designing an efficient dairy farmstead layout. Some of these principles have been incorporated into the design of a trial pie-shaped layout which has been constructed in the past year and which will be studied as a means of corroborating the tentative conclusions.

The farmstead planning discussion in Area 10, E, applies to all types of farmsteads, including dairy.

2. Bio-engineering studies. Basic fundamental studies on the relationships between environment and various dairy animal health and production factors were continued in the psychroenergetic laboratory, and related facilities at Columbia, Mo., in cooperation with the Missouri Agricultural Experiment Station. A 9-week test was made on 6 lactating Holstein cows to test their ability to acclimate to 85° F. temperature and 50% relative humidity (RH). Measurements at 85° F. were compared with those at 65° F. and 50% RH immediately preceding and following the 85° F. exposure.

Individuals varied in initial and acclimation responses to heat exposure with respect to their milk production, feed and water consumption, loss of body weight, and rise in body temperature. Losses in production were significant ($P < .01$) during the 9-week exposure in 4 of 6 cows. Three of the 6 were much more heat-sensitive than the other three. The heat-sensitive group lost 407 pounds in 9 weeks; the others lost only 166 pounds. Production decreased in all cows during the first 2 weeks at 85° F. A significant ($P < .05$) recovery occurred in the less heat-sensitive group, but not in the other group, during the last 7 weeks at 85° F. Milk production in the three highest producers dropped 449 pounds but only 151 pounds in the three lowest producers. Feed and water showed acclimation trends but no significant group differences.

Cooling inspired air to about 60° F. and 50% RH allowed recovery of milk production for animals previously exposed to 85° F. and 50% RH, and with these conditions continuing to surround the animals' bodies at the time of the test. This recovery was evident in 3 of the 4 cows undergoing preliminary testing. Insulated units installed so as to surround the head of a stanchioned cow permitted control of the conditions of the inspired air. Actual amounts of recovery will not be known until the persistency of lactation can be computed. Cows showing a 1° F., or higher, rise in rectal temperature in response to the 85° F. room condition (following a 65° F. room condition) showed a decrease of about 1° F. when inspiring cooled air in the hot environment.

Physiological and genetic evaluation of dairy cattle also was continued at Missouri. Standardized environmental conditions were used to physiologically evaluate the 12 cows entering the climatic laboratory for tests during the year. This is a continuation of the long-range study reported last year. Responses of the animals were again quite varied. At a condition of 88° F. and 40% RH, maximum differences among individuals were 4.2° F. in rectal temperature, 40 respirations per minute, and 20 heart beats per minute. These differences are similar to those reported among individual cows last year.

Heat sensitivity of lactating cows was studied in tests initiated at Missouri to evaluate the potential of using a standard hot environment for determining the heat sensitivity. A single-cow hot box was developed to provide the standard environment of 110° F. with no solar load. The primary measure was the length of time required to cause an arbitrarily selected rectal temperature rise of 2° F., thus providing a line of given slope for each cow tested. Theoretically, this slope will be a measure of heat sensitivity. Tests of repeatability of slope values were made on 2 cows and, in general, the slopes were quite consistent for each cow. Thirty-six randomly selected lactating cows were later subjected to the standard environment. These cows apparently fall into 2 groups, one group having a low rate of rectal temperature rise (heat tolerant) and the other having a higher rate of rise (heat sensitive).

Environmental measurements on a Missouri dairy farm were started during January 1963. In conjunction with a nutrition study involving 2 lots of 20 lactating Guernsey cows each, a weather station was set up to record dry bulb and black globe thermometer temperatures and air velocity in the outside lot areas. Hygrothermographs were placed to record air temperature and relative humidity in the loose housing area within the open-front shelter. This study is still in progress.

Production methods for cooling dairy cattle were studied at Tifton, Ga., in cooperation with the Georgia Station. A continuing study was made of the comparative value of shade versus shade plus fans plus water sprays on lactating Jersey cows. Two groups of nine cows each were held in drylot at all times during a 63-day test except for the milking time. The only difference between the two groups was the shelter system. There was no difference in rate of decline of milk production between the two treatments. However, mastitis was a serious problem during the test and may have influenced the results. Activity observation at 15-minute intervals on 10 days showed that during daytime the cows in both treatments used the shades the same percent of time and spent essentially the same time eating. Animals in both treatments spent one hour at the feed trough in daytime and 2-1/2 hours at night.

3. Plan development. At Beltsville, Md., a plan was developed for a combination hay storage and feeding shed suitable for dairy and beef cattle use throughout the South (and to some extent in other regions). A plan was also developed for a cattle feeding shelter suitable for the South and West and having covered feed bunks with poles in the center so that an auger can work between the poles or a self-unloading wagon can empty directly into the bunk. These plans were developed for the Cooperative Farm Building Plan Exchange. (Note: These are the same plans listed in B-3).

B. Beef Cattle Engineering

1. Hot, arid, climate. At El Centro, in the Imperial Valley of California, in cooperation with the California Station, four pens of beef cattle were used to compare the effects of a cooled shade, sprays, and spot refrigerated coolers, with a typical shade. The cooled shade was constructed under one of the regular shades. The sub-roof was made of excelsior pads supported on chicken wire. Spray nozzles were placed above this and their flow was regulated by a time clock and solenoid values. A plenum chamber was made by enclosing the sides with plastic film. Two large, slow-speed fans forced air into this chamber, past the sprays and through the excelsior onto the cattle. In another pen, two 1-hp commercial air coolers were mounted so that the air stream from one, about 500 cfm, blew across the backs of the animals; the stream from the other cooler blew down onto the animals. Two other pens had two sprinklers in each. Water flow was timed so as to minimize muddy conditions under the shades. Hereford yearling heifers were used in a feeding trial from July 18 to October 31, 1962. The weight gain and feed conversion are shown below:

	Controls (shade only)	Water Sprays	Evaporatively Cooled Shade	Refrigeration Units
Number of animals	6	6	5	5
Initial wt. lb.	60.4	60.7	81.0	85.1
Daily gain, lb.	2.10	2.04	2.03	2.40
Gain/100 lb. feed	11.4	11.5	10.9	12.2

There were no particular benefits from any treatments other than the refrigeration units. Observation indicated the animals preferred to use the unit discharging downward. Feed consumption and daily gains were increased over control animals although differences in energy gain or corrected carcass weight were not significant.

2. Hot, humid, climate. At Columbia, Mo., in cooperation with the Missouri Station, fifty-four grade Hereford heifers were randomly placed in four pens with the following treatments:

(1) Control - inside and outside pens constructed as other three except radiation panels were not cooled.

(2) Condensate drip from cooled panels channelled to outside drain.

(3) Condensate drip allowed to fall into pen.

(4) Same as (3) but animals allowed free access to outside pens.

Average daily gains for the 11-week period were: (1) 1.28 lb.; (2) 1.42 lb.; (3) 1.39 lb.; and (4) 1.37 lb. Providing radiation cooling for growing beef calves did not markedly improve gains although a trend favorable to radiation cooling was apparent. However, the animals were small and were on growth rations. Future tests would be more meaningful with fattening animals.

3. Plan development. See plans listed in A-3.

C. Swine Engineering

1. Effect of humidity on swine. At Davis, Calif., in cooperation with the California Station, the effect of humidity on swine is being investigated in three chambers, each with 20 sq. ft. of floor space, built into a psychrometric chamber. Temperature and humidity of each can be controlled. These are basically insulated wood boxes with wire mesh floors. Air is introduced through separate humidifying chambers to plenum chambers above each house. Air is discharged from each house via the floor. Each house has a 2-hole self-feeder and automatic watering cup. On February 20, four cross-bred pigs (2 barrows and 2 gilts) were placed in each house. They were born January 8, 1963, and weighed 20 pounds each at the start of the test. One group will be kept at a constant temperature-humidity index, THI (73° F. dry bulb and 88° F. dew point) to market weight. A second group will be started at this same THI (this is theoretically optimum THI for this size pig) and the THI will be adjusted downward by hog weight so as to maintain these pigs always at the same optimum THI. The third will be given the opposite treatment so they will be under stressing conditions at all times. This is the first of a series of tests designed to determine the effects of humidity on weight gain, health, and feed conversion of swine.

2. Hot, arid climate. At Davis, Calif., in cooperation with the California Station, studies of sprinkler operation continued in a program designed to determine the best types of nozzles and methods of operating them for maximum effectiveness in cooling swine. Four outside pens of 10 Duroc pigs each were equipped with various kinds of sprinklers that were operating for different periods between 10 a.m. and 8 p.m. Each pen had two Monarch F-110 nozzles operating as follows:

No. 6.4	2-1/2 minutes out of 15
No. 6.4	15 minutes out of 30
No. 6.4	Continuously
No. 2.0	Continuously

The daily gains of pigs with continuous sprays (No. 6.4 nozzles) were greater than all others except for those with sprays on 1/2-time (5% level). There were no differences in gains among the 1/6-time, 1/2-time and continuous fine sprays (No. 2.0). Feed conversion rates could not be tested statistically because the animals were group fed; however, in terms of actual feed conversion rates there does appear to be some advantage in using sprays operating half-time, particularly if supply or drainage of water is a problem. The daily rates of water used by each pen were: 1/6-time, 15 gallons; 1/5-time, 50 gallons; continuous, 100 gallons; and continuous fine spray, 32 gallons.

Tests of air conditioned houses for swine were continued at El Centro, Calif., in cooperation with the California Station. The first test was reported last year. Two air conditioned houses 6' x 14' x 4-1/2' were used to house 8 cross-bred hogs in each. Inside air temperature was maintained at about 70° F. These houses were identical except a feeder and waterer were placed inside in one house and outside of the other. The second house had a dummy feeder so floor space was not a variable. A control group of pigs had access to a shaded wallow. Analysis of the two years of data indicate no significant differences in daily gain, carcass yield, or backfat thickness that could be attributed to air conditioning. However, each year the air conditioned hogs gained 0.1 lb. more per day than animals with access to shaded wallow. Placing feed and water inside the house had no effect on gains. Feed consumption was significantly greater when the feeder was inside the house, although feed utilization was not superior for this treatment. This test will be repeated a third year.

3. Hot, humid climate. The value of shade and shade plus fogging for growing-finishing pigs in hot, humid climates was studied at Tifton, Ga., in cooperation with the Georgia Station. A movable shade (12'x16') on skids was designed for this study, in which 32 pigs (avg. 61.6 lb. each) were held in small pasture lots (8 pigs per lot), two lots had shade plus fogging under the shade and two lots had shade only. Since two rations were fed, no conclusions of significance could be drawn from this first year's data, but there was a trend to benefit from sprinkling as far as weight gains were concerned. This test will be repeated.

The value of shade and shade plus fogging for gestating sows and gilts in a hot, humid climate was also studied at Tifton. A movable shade (12'x16') on skids was designed for this study, in which 16 sows and 16 gilts were in temporary pasture lots (8 animals per lot), two lots had shade plus fogging under the shade and two lots had shade only. Average rectal temperatures and respirations per minute for the animals having access to the shade and fogging were 101.2° and 60.6, respectively, while the same measurements for the animals having shade only were 103.0° and 143.3, respectively. However, the average number of live pigs farrowed, birth weight of live pigs, number of pigs weaned, and adjusted 56-day weight of pigs were essentially equal for the two treatments. This is only one year's data and it is estimated that three to four years' data will be required for analysis.

4. Type of housing - level of feeding. At Escalon, Calif., studies on type of housing and level of feeding of swine were continued in cooperation with a major hog producer. Two replicates were reported last year. The third and final replicate is included in the data presented here. The three replicates provide a year-around representation of the data. These were as follows:

	No. Pens	Pigs/Pen	Level of Feed, %
March 30 - June 13, 1961	12	10	63, 71, 78, 86
July 21 - October 16, 1961	9	10	71, 78, 86
January 4 - March 26, 1963	9	10	71, 78, 86

The levels of feed were based on certain percentages of those recommended on the basis of live weight by the National Research Council. The three types of housing were (a) a totally enclosed insulated building, (b) an extension of this building, but without sidewalls, and (c) an open shed with a concrete floor. Differences in gains in weight due to differences in housing and feeding levels were both highly significant (1%). Hogs fed in the outside shed (11 sq. ft. per pig in all pens) gained weight slower and required more feed per unit of gain than in the totally or partially enclosed houses. Pigs in the outside pens also had lower specific gravities and therefore were less lean. Feed per unit of gain was significantly higher for the 86% feeding level than the 78 or 71% levels. Feed conversion was greatest in the spring and lowest in the winter. Four hogs from each group in each replicate were slaughtered and their specific gravity measured.

5. Stand-up feeding. In cooperation with the California Station, stand-up feeding of pigs was investigated at Davis as a means of improving the commercial carcass cuts of swine. Feeders were designed so that pigs would stand on their hind legs to eat. The purpose was to determine if this type of exercise affected commercial pack cuts. In the first test, started January 8, 1962, four groups of six Duroc barrows weighing 120 pounds were randomly assigned, two groups to the standing treatments and two groups fed in ground-level troughs. They were fed for 49 days this way. Carcass studies indicated no significant differences between treatments as to yield, carcass length, backfat thickness, eye muscle area of the tenth rib cut, carcass specific gravity, and percentage of the loin, shoulder, or belly of the carcass. Backfat thickness, eye muscle area and specific gravity favored the standing pigs. The percentages of ham, or ham and loin, were greater in the standing pigs. A second trial was conducted between June 7 and October 1, 1962. Three pens were used with 11 pigs per pen weighing initially 60 to 70 pounds each. Two groups were fed in ground-level troughs, one free choice and the other restricted (twice daily) to the amount of feed consumed by the stand-up pigs. The third pen had two 6-ft. long stand-up troughs. New troughs, each 7-ft. long, were constructed and installed on August 7. One day of every other week a 12-hour activity check was made from 7 a.m. to 7 p.m. These data have not been completely analyzed, but the results were generally the same as the first group with the percent loin being greater in the standing pigs. This test will be repeated.

6. Slatted floors. Work has been initiated in cooperation with the Minnesota Northeast Experiment Station at Duluth, Minnesota, to study the use of slat floors as compared with the open, solid concrete feeding floor. In this study the labor requirements, production performance and slat materials (including wood, concrete and steel) are being observed.

7. Plan development. Based on the research at Tifton, Ga., reported in C-3 (above) and D (following), a plan for a portable shade for hogs was developed for the Cooperative Farm Building Plan Exchange.

D. Poultry Engineering

1. Calorimeter studies. At Beltsville, Md., in cooperation with AH, the 300- to 380-day old second-generation inbred strain of heat-resistant Arizona SCWL laying hens was checked for heat dissipation characteristics at 65°, 85°, and 95° F. (These birds were developed at the USDA Southwest Poultry Experiment Station, Glendale, Arizona). Comparison between Arizona and previously tested Beltsville strains of SCWL showed some strain differences. Mainly these differences were within the 95° F. tests where the Arizona strain ate 26% more feed and had a 43% greater rate of heat dissipation. However, water consumption was about the same for each strain, as was the ratio of latent to total heat dissipation. These results suggest that the Arizona birds may attain high egg production rates in hot weather through more efficient utilization of feed.

Also in the calorimeter at Beltsville, the following schedule was adopted in a long-term study of the effects of temperature on growth and heat and moisture production of Athens Randombred broilers:

Trial	Temperature Levels of Calorimeter A	B
1	5 C	30
2	25	10
3	30	5
4	10	25
5	20	15
6	15	20

In this schedule, the calorimeters and the temperature levels were randomized, with humidity set at about 75% RH. Trial I was completed March 15, 1963.

2. Southeast poultry disease laboratory. Considerable engineering time was spent in design of equipment and facilities for the new poultry disease laboratory in Athens; this facility (still not completed) will be used in cooperation with ADP, AH, and the Georgia Agricultural Experiment Station. In addition, an environmental cabinet was designed and initial performance tests were started. This will serve as a prototype for 8 to 12 such cabinets to be used in the laboratory. Some parameters included in the design were:

(1) Floor space for 30 to 40 broilers.
(2) Air temperature programming, 20 to 110° F. range.
(3) Relative humidity programming, 20 to 90% range.
(4) Sidewall temperature programming, 20 to 110° F. range.
(5) Roof or cover temperature programming, 20 to 130° F. range.
(6) Floor temperature programming, 30 to 100° F. range.
(7) Adjustable ventilation rate 0 to 10 cfm per bird.
(8) Adjustable air flow in cabinet, 0 to 20 cfm per bird.
(9) Air pollution and control.

3. Field observations on relation of housing to disease in South Central States. At State College, Miss., in cooperation with AH and the Mississippi Station, feed conversion, condemnation, and growth rate of broilers in insulated houses were compared with growth in comparable broiler houses that were not insulated. Results show that other construction and management factors have to be controlled to make insulation an effective means of broiler house environment control. If brooders are not properly regulated, if ridge vents are left open, or if side curtains are not properly adjusted or are in poor condition, added insulation has little affect on operating conditions and consequently upon feed conversion, condemnation or growth rate.

A comparison of broiler houses with the length oriented in an east-west direction was made with those with the length in a north-south direction. The four broods (88,000 birds) studied showed that the broilers grown in east-west orientated houses had less condemnation and as good or better growth rate than those grown in the north-south oriented houses.

Preliminary observations of brooding systems showed that uniform and/or adequate temperatures are not being maintained.

4. Influence of turkey housing environment on disease. At St. Paul, Minn., four tests have been completed comparing infected turkeys grown in environmental conditions differing mainly in ambient temperature values by 15° F. to 20° F. The infectious agent has been the S_6 strain of mycoplasma gallisepticum. Upon completion of each test the turkeys have been New York dressed in a processing plant and then inspected in one of the University laboratories. Three areas of infection were scored numerically from 0 to 3 with the severest lesions receiving a score of 3. A bird with a score of 2 or 3 in at least two areas was classed as condemned.

The data from the first 2 experiments plotted as percent condemnation against average pen temperature indicates a reduction in condemnations with increasing pen temperatures up to 70° F. In the third test the pen temperatures were 70° F. and 79° F. In this test the condemnations were 10% and 28%, respectively. It was theorized that the higher temperature was producing a heat stress. The results of a fourth test, at 40° and 60° F., did not fit into the graph of the previous tests. A plan is underway to eliminate this particular disease from the turkey hatching egg flocks in the State.

The studies bring to light the complex nature of studies involving disease and environment. One of the greatest problems is the loss of wingbands during the plucking operation. Large differences were obtained between replicates with no leads as to the reasons.

5. Plan development. At Beltsville, Md., the design for a laying house containing colony cages was completed for the Northeastern Region and was included in the Cooperative Farm Building Plan Exchange. The ventilation system uses the solar heat gain of the roof for tempering ventilation air. The plan incorporates the results of California research on cage fabrication and Michigan research on manure flushing. It also illustrates use of two-level illumination to conserve power, and presents the concept of sizing summer ventilation for maximum evaporative temperature depression.

E. Livestock Shades and Shelters

At Tifton, Ga., in cooperation with the Georgia Station, a study was continued in an effort to define the best height for cattle shades in a hot, humid climate. Observations in 1960 indicated an advantage, in terms of lower black globe temperatures at animal level, for a 6-ft. shade compared to others 9 and 12 ft. high. During a limited series of tests the past year, no differences were noted. This test will be repeated with the inclusion of directional radiometer measurements.

F. Sky Radiosity Studies

A start was made at Davis, Calif., (dry climate, clear sky) and at Columbia, Mo., (humid climate, cloudy sky) toward a study of the downcoming radiant fluxes on an animal or building, in cooperation with the respective State Stations. The quantity, quality, and variation of these with azimuth and altitude directions will be important in the design and orientation of farm animal shelter and storage buildings. Much of the preliminary work was concerned with investigation of necessary instrumentation.

G. Reducing Pesticide Residues in Animal Products

Field tests of experimental automatic walk-through sprayers for controlling flies on cattle, conducted at Kerrville, Texas, in cooperation with the Entomology Research Division, indicated that they controlled horn flies on cattle as well as did power sprayers used in pens, and used 37% less insecticide. The insecticide used was one of the two that can be sprayed directly on lactating cattle without leaving residues in the milk. The sprayers appeared to be suitable for herds that must come to specific watering spots in their daily routine or that must be milked (in the case of dairy cattle). Operation of the sprayers during the field tests indicated that reliability without supervision and speed of operation are factors which must be optimized for the most efficient use.

In developing and evaluating equipment and procedures for reducing chemical hazards associated with the control of livestock insects a measure of the amount and location of the spray applied to each animal is very important. At Kerrville, Texas, methods of quickly and accurately measuring the spray retention have been evaluated and a number of them discarded. The use of a fluorescent dye tracing technique is presently being studied as a means of measuring both distribution and retention. Preliminary trials indicate that only 38% of a one-gallon spray of clear water will remain on a mature Hereford cow when the application is made with a power spray.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

A. Dairy Cattle Engineering

Johnson, H. D., Ragsdale, A. C., Berry, I. L., and Shanklin, M. D. 1962. Effect of various temperature-humidity combinations on milk production of Holstein cattle. Missouri Agr. Exp. Sta. Bul. LXIX.

Kibler, H. H., Yeck, R. G., and Berry, I. L. 1962. Vaporization rates in Brown Swiss, Holstein, and Jersey calves during growth at constant 50° and 80° temperatures. Missouri Agr. Exp. Sta. Res. Bul. LX.

Wayman, O., Johnson, H. D., Merilan, C. P., and Berry, I. L. 1962. The effect of ad libitum or force feeding of two rations on lactating dairy cows subject to temperature stress. Jour. Dairy Sci. 45:1472-1478.

Berry, I. L., Shanklin, M. D., and Johnson, H. D. 1962. Physical factors affecting thermal insulation properties of hair coats of dairy cattle. Jour. Dairy Sci. 45:669.

Johnson, H. D., Hahn, L. Kibler, H. H., and Merilan, C. P. 1962. Heat acclimation effects on lactation and related physiological responses of cattle. Jour. Animal Sci. 21:1025.

Johnson, J. C., Southwell, B. L., Givens, R. L., and McDowell, R. E. 1962. Interrelationships of certain climatic conditions and productive responses of lactating dairy cows. Presented before Am. Dairy Sci., College Park, Maryland.

Johnson, J. C., and Givens, R. L. 1962. Single versus frequent observations for estimating some summer climatic conditions in South Georgia. Presented at Am. Dairy Sci., College Park, Maryland.

Johnson, J. C., and Givens, R. L. 1962. Summary of studies on the effects of shade, fans and sprinklers on summer milk production. Presented at Annual Dairy Field Day, Gainesville, Florida.

Watering trough (continuous flow) for cattle. 1962. (Exchange Plan No. 5909). USDA Misc. Pub. No. 898, April. (Note: Also listed under B, below).

The following cooperator's publications are the result of cooperative work and report related non-engineering phases of the research:

Kibler, H. H. 1962. Energy metabolism and related thermo-regulatory reactions to thermal stress in the 50° and 80° acclimated dairy heifers. Missouri Agr. Exp. Sta. Res. Bul. LXI.

Cargill, B. F., Stewart, R. E., and Johnson, H. D. 1962. Effect of humidity on total room heat and vapor dissipation of Holstein cows at 65, 80 and 90° F. Missouri Agr. Exp. Sta. Res. Bul. LXIII.

Lundgren, R. G., and Johnson, H. D. 1962. Effects of temperature and control feeding on thyroxine I^{131} degradation rates and serum protein fractions of dairy cattle. Jour. Dairy Sci. 45:689.

Johnson, H. D. 1962. Comfort zone for dairy cows. Hoard's Dairyman 107:15, August 10.

B. Beef Cattle Engineering

Garrett, W. N., Kelly, C. F., and Bond, T. E. 1962. Total and shaded space allotments for beef feedlots as affected by ration in a high temperature environment. Jour. Animal Sci. 21:794-797.

Watering trough (continuous flow) for cattle. 1962. (Exchange Plan No. 5909). USDA Misc. Pub. No. 898, April. (Note: Also listed under A, above).

Davis, R. L., and Edgerley, W. F. 1963. Feedlot and ranch equipment for beef cattle. USDA Farmers' Bulletin No. 1584, rev. January.

McCormick, W. C., Givens, R. L., and Southwell, B. L. 1963. Effects of shade on rate of growth and fattening of beef steers. Georgia Agr. Exp. Sta. Technical Bul. N. S. 27, February.

C. Swine Engineering

Heitman, Hubert, Hahn, L., Bond, T. E., and Kelly, C. F. 1962. Continuous versus intermittent observations in behaviour studies with swine raised in confinement. Animal Behavior 10:165-167.

Heitman, H., Hahn, L., Bond, T. E., and Kelly, C. F. 1962. The effects of modified summer environment and swine behavior. Animal Behavior 10: 15-19.

Heitman, H., and Bond, T. E. 1962. Percentage of ham and loin increases when pigs stand to eat. California Agriculture 16:8-9.

Bond, T. E., Heitman, H., Hahn, L., and Kelly, C. F. 1962. Space allowances for hogs grown in confinement. California Agriculture 16: 9-10.

Kelly, C. F., Bond, T. E., and Heitman, H. 1962. Direct air calorimetry. Presented at ASAE Meeting, Washington, D. C. as Paper No. 62-424.

Bond, T. E., Kelly, C. F., and Heitman, H. 1962. Effect of diurnal temperature upon swine heat loss and well being. Presented at ASAE Meeting, Washington, D. C. as Paper No. 62-427.

Bond, T. E. 1963. Summer comfort with water. Proc. Animal Husbandry Swine Day, Davis, California, pp. 5-13.

Bond, T. E. 1963. Swine environmental research in California. Presented at Pacific Coast Section, ASAE, San Francisco, California as Paper No. P.C. 63-9.

Bond, T. E. 1963. New results from farm animal environment studies. Presented before Pacific Coast Section, ASAE, San Francisco, California as Paper No. P.C. 63-12.

The following cooperator's publications are the result of cooperative work and report related non-engineering phases of the research:

Finn-Kelcey, P. G. 1963. Comfort conditions for fattening swine. Proc. Animal Husbandry Swine Day, Davis, California, pp. 41-47.

Garrett, W. N. 1963. Effects of experimental environments on fattening swine in a hot climate. Proc. Animal Husbandry Swine Day, Davis, California, pp. 15-23.

Heitman, H., and Moore, H. A. 1963. Type of housing and level of feeding for swine raised in confinement. Proc. Animal Husbandry Swine Day, Davis, California, pp. 25-34.

D. Poultry Engineering

Ota, H., and McNally, E. H. 1962. Poultry investigations with the Beltsville Respiration Calorimeters. Presented at ASAE Meeting, Washington, D. C., as Paper No. 62-426.

Junnila, W. A., and Otis, C. K. 1962. Which ventilation system for you? Turkey World, V. 37, No. 9, September.

Teter, N. C., and Ota, H. 1962. Insulating materials and vapor barriers, their value and application. Presented at Broiler Housing Seminar, Georgetown, Delaware.

Ota, H., and McNally, E. H. 1962. Studies on Arizona and Beltsville strains of SCWL. Abstract, presented at NE-8 Committee Meeting, New York City.

Wang, J. Y., and Borger, G. L. 1962. Bibliography of agricultural meteorology. University of Wisconsin Press. H. Ota was joint compiler for section on poultry environment.

Ota, H. 1963. Engineering problems in broiler production. Maryland Poultryman.

Ota, H., and McNally, E. H. 1963. Design criteria for laying house moisture and temperature control. Presented at Commercial Egg Clinic, Texas A & M College, College Station, Texas.

E. Livestock Shades and Shelters

Hahn, L., Thom, H. C. S., and Bond, T. E. 1962. Livestock shelter design. Agricultural Engineering 43:704-709.

F. Sky Radiosity Studies

None

G. Reducing Pesticide Residues in Animal Products

Berry, I. L., and Hoffman, R. A. 1963. Factors affecting the design of self-activated livestock sprayers. Presented at Southwestern Branch Entomological Society Meeting, Houston, Texas, February 10-12.

Hoffman, R. A., and Berry, I. L. 1963. Results of 1962 Texas field tests of Ciodrin (Shell SD-4294) for control of flies attacking cattle. Presented at Southwestern Branch Entomological Society Meeting, Houston, Texas, February 10-12.

AREA NO. 10: CONSTRUCTION STANDARDS, WATER SUPPLY, WASTES DISPOSAL, AND FARMSTEAD PLANNING

Problem. The inventory value of farm buildings in the United States exceeds $28 billion. During 1960, more than 1/2 billion dollars were spent on repair and maintenance of these buildings and an additional 1-1/2 billion was spent for new construction, additions, and major improvements. The construction of many of these buildings is wasteful of materials. The strength of structural members is frequently much greater than the joints that connect them. Assumed loads are sometimes unrealistically high and at other times so low that failures occur. Better information on the actual loads--contents, wind, and snow--is needed. The basic frames of farm structures are often statically indeterminate and defy the accurate application of conventional indeterminate analysis techniques. Two research approaches are needed to develop readily applicable design procedures--proof testing and development of basic design formulas. Rural fires account for 800 deaths and 175 million dollars worth of property damage annually. Information is needed on means of reducing these losses without imposing excessive expense on construction.

In many localities urban building codes that may be unduly restrictive are being extended to cover farms. The hazards of public occupancy and damage to the property of others are not present to the degree that they are in urban areas. Those who draft building and fire codes need design information that would be realistic for farms.

An adequate supply of satisfactory water is essential to the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead--both in quantity and quality. The "old well" is less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truck load at considerable cost; others are developing farm ponds as sources of farmstead water; some continue to operate with a supply that is becoming less and less adequate.

Surface waters normally require disinfection as a safeguard against waterborne diseases such as typhoid, dysentery, other gastro-intestinal disorders, and infectious hepatitis. Often they also require filtration and other treatment to remove undesirable foreign material. Deeper ground waters are often highly mineralized (hardness, iron, sulphur, and others), and expensive or impossible to treat adequately. Data on water demands and water systems requirements of the modern farmstead are needed to guide farmers in planning water systems and selecting equipment, to enable extension workers to adequately advise farmers, and to guide equipment and appliance manufacturers and sanitary code-making bodies. Simpler, more reliable, and less costly methods and equipment are needed for treating farmstead water supplies to improve their quality.

Disposal of organic wastes--principally sewage and manures--is becoming more and more of a problem on the modern farmstead. The cattle, hogs, horses, sheep, and poultry on farms in the United States produce more than 2 billion tons of manure annually. The problem is particularly acute with respect to confinement-type livestock operations on the fringe of metropolitan areas--where the total amount of manure is concentrated in the confinement area. Under these conditions it is difficult to avoid creating a sanitation hazard or a public nuisance. Economical, sanitary means of disposition need to be developed. Among means that need to be investigated are lagoons, irrigation systems, subsurface absorption systems and reclamation. Development of improved methods for disposing of sewage in those rural areas where conditions are adverse to the conventional septic tank system (high ground water, shallow rock, non-absorptive soils, restricted areas) is needed.

The arrangement plan of the farmstead has an important bearing on its efficiency, appearance, and livability. For example, convenient locations for feed and bedding storage ease the distribution chore. A 40-cow dairy herd will use approximately 240 tons of silage, 60 tons of grain, 40 tons of hay, and 20 tons of bedding annually. Research is needed to evaluate the various planning factors in the light of current equipment and practices and to develop planning principles and guidance materials for the benefit of farmers--particularly those contemplating changes.

A 1957 survey of about 25 well-informed leaders of the agricultural community in each state reported the following as the most urgent problems needing solution:

1. How to adapt existing buildings for more efficient production.
2. Lower cost, more efficient, and more flexible buildings for tomorrow.
3. Engineered farmstead design.
4. Mechanization of materials handling.
5. Better utilities--water supply, wastes disposal, and electric service.

USDA PROGRAM

This is a continuing long-term program involving engineers and architects engaged in basic and applied research on structural aspects of farm buildings, farmstead water supply, farmstead wastes disposal and farmstead planning. Protection of farm families and animals against radioactive fallout has recently become of concern. The program is cooperative with selected State Agricultural Experiment Stations.

A. Meteorological factors affecting the design of farm structures, such as climate and weather (wind, storms, frost, etc.), are studied at Beltsville, Md., and selected field locations. A contract let to the Weather Bureau, USDC, for data on snow load probabilities, was completed during the year.

B. Construction standards, such as serviceability and safety, for design of farm buildings are studied at Beltsville, Md., and selected field locations. Liaison is maintained with the American Society of Agricultural Engineers, American Standards Association, National Safety Council, National Fire Prevention Association, and other organizations concerned with standards and safety in farm structures.

C. Materials and construction methods for farm buildings are studied at Beltsville, Md.; at Blacksburg, Va., in cooperation with the Virginia Agricultural Experiment Station; and at State College, Miss., in cooperation with Animal Husbandry Research Division and the Mississippi Agricultural Experiment Station.

D. Water supply and wastes disposal for the farmstead are studied at College Park, Md., in cooperation with the Maryland Agricultural Experiment Station. Liaison is maintained with the Public Health Service, the Water Systems Council, American Society of Agricultural Engineers, and other organizations concerned with rural sanitation.

E. Farmstead planning studies are made at Beltsville, Md.; at St. Paul, Minn., in cooperation with the Minnesota Agricultural Experiment Station; and at Davis, Calif., in cooperation with the California Agricultural Experiment Station.

F. Fallout protection work for the farmstead is conducted at Beltsville, Md., and selected field locations. Liaison is maintained with the Office of Civil Defense, DOD, and other appropriate agencies.

The Federal effort in this Research Area totals 7.7 professional man-years. Of this number 0.1 is devoted to meteorological factors; 0.1 to standards for serviceability, safety, etc.; 1.9 to materials and construction methods; 2.0 to water supply and wastes disposal; 1.2 to farmstead planning; 1.9 to fallout protection; and 0.5 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Meteorological Factors

Preliminary maps showing distribution of snow load probabilities for different climatic regions of the United States were completed during the year by the Weather Bureau under a contract arrangement. These maps are based on 10 years of Weather Bureau records on water equivalent of snow pack at their first order weather stations.

B. Construction Standards

At Beltsville, Md., analysis of the distribution of snow load probability data from the Weather Bureau maps indicated that they do not fit the mathematical model well at the 25 and 50 year recurrence intervals. Redistribution of the data will be made and maps prepared for use as loading standards for design of farm buildings.

C. Materials and Construction Methods

1. Stressed-skin panels. At Blacksburg, Va., continued research into new methods of utilization of materials resulted in improved shear connections in insulated panels faced with 1/2-inch thick portland cement mortar, reinforced with prestretched steel wire. Panels were developed that are 37 percent stronger in bending than those previously built. Panels were cast 32' long and later sawed to length. Temperature differential of 50° across the panels did not damage them. Commercial production of the panels is feasible.

2. Hyperbolic paraboloid (HP) shapes for farm structures. At Beltsville, Md., testing of various elastic materials shaped into hyperbolic paraboloids has shown conclusively that the pure membrane theory advanced for design of concrete HP's is inadequate. Secondary stresses have been determined to be more important than the membrane stress. Bending of edge members and distribution of the configuration of an HP toward a new shape--compressive arch for materials like concrete, and tensile catenary for materials like plywood--that naturally utilize the capability of the material, dictates development of more sophisticated and more accurate design formula for these shapes.

Also at Beltsville, plywood covered with a thermo-setting elastomer was used in the erection of a pentagonal building of hyperbolic paraboloids. The new shape used for investigative probing into possibilities of better space arrangement of structural members and in use of non-structural coverings for structural strength is one of two special designs in use of HP's. The other, in the form of a 1/4 scale model, employed identical HP's for wall and roof units. Currently tests are being made on practicability of fabricating quadrants of a unit in approximate 8' x 8' dimensions so the quadrants can be fastened together.

3. Rotational strength of nailed joints. Research at Blacksburg, Va., on resistance of nailed joints to rotation, showed a correlation of $r = 0.91$ in the linear regression equation of:

$M/J_m = 44.51 + 24559\ \theta$

M = Moment on a nailed joint, inch pounds

J_m = Joint modulus, computed as the maximum lateral resistance of a nail times the ratio of the summation of the square of nail distances to the center of rotation of the joint divided by the distance to the fartherest nail from the center.

$$J_m = F_{max.} \frac{\sum r^2_i}{r_{max.}}$$

θ = Joint rotation in radians

This equation held for 108 tests made on lap nailed joints in 2 x 4's, 2 x 6's, and 2 x 8's and thus may be used to predict strength of nailed joints.

4. Rigid timber frames. At Blacksburg, Va., a series of full scale tests on knee braced rigid frames with trussed overhangs on each side proved that assumptions made in analytical design of the system were valid, but the experimental design was not rigorous enough to extrapolate the results to prove validity of assumptions for other similar designs.

5. Air flow resistance of curtain wall materials. At State College, Miss., a study of the air flow resistance of curtain wall materials used on broiler houses gave basic data for computation of air movement through curtain walls. Limited experiments with broiler production in houses with air-tight curtain walls versus those with air-permeable curtain walls indicated that some degree of air permeability is desirable.

6. Grain bin bolt washer exposure tests. At the request of ASCS, high temperature, soak and bake, freeze-bake, and ozone exposure tests have been made at Blacksburg, Va., on washers to go under the heads of grain bin bolts. Final comparative criteria tests between the test washers and conventional neoprene washers will include tests for leaks under pressure in a specially constructed pressure chamber.

7. Plan development. A plan for a 40-foot truss for use in pole construction was drawn at Beltsville, Md., for inclusion in the Cooperative Farm Building Plan Exchange. The design was developed and field tested by the Oregon State University. Plans developed for crop structures, farmhouses, and livestock structures are reported in Areas 7, 8, and 9, respectively.

D. Water Supply and Wastes Disposal

1. Farmstead water demands. Studies on farmstead water demand and requirements are continuing in Maryland, in cooperation with the Agricultural Experiment Station.

Development and trial use of a digital automatic water use recorder for obtaining data on the complex water use involved in the operation of the present-day dairy farmstead is nearing completion. This equipment is being developed as a research instrument which will automatically record the time, amount and rate of water use at numerous points on the farmstead. In the process of developing this equipment, water use data are being collected on four dairy farms in the State of Maryland. These farms have excellent production records, good physical plants and good management, so the data obtained are expected to present water use information which will point up the requirements of good dairy farms. The data are being analyzed in a data reduction process and, through the use of analytical models, the results will be presented as basic water use and design requirements for dairy farmstead water systems. Work is also being conducted to determine the analytical model which will provide the optimum design basis. It is anticipated that in using such an analysis, the water system will not be designed to meet the extreme case but will provide the optimum adequate water system for the requirements of the particular farmstead.

2. Farmstead manure disposal. Studies are underway at College Park, Md., in cooperation with the Maryland Agricultural Experiment Station to determine design requirements for manure disposal lagoons. In an effort to establish the first basic design requirement, research equipment and techniques are being developed to determine the Biochemical Oxygen Demand (BOD) requirements of the various animal and poultry manures. Initial tests have shown that cow manure from animals fed silage only has a 5-day BOD of 1/2 pound of oxygen per pound of dry weight. It is expected that it will be necessary to determine the BOD requirements of manure from all farm animals as well as the effect of all the components of various feed programs now being used.

Laboratory work is also underway to determine the relative soil sealing effects of the various farm animal manures when added to disposal lagoons. Initial work has been with the Manor soils found in Howard County, Maryland. Using a loading rate of .01 pound (dry weight) of manure per day per cubic foot of water in a soil bin with standardized porosity, it was found that different types of manure sealed the soil in different periods of time. The respective sealing times found for the various manures were: Cattle, 20 days; hogs, 39 days; chickens, 59 days (averages of 8 trials each). These values are for the purpose of showing relative sealing effects only and are not directly applicable to undisturbed soils.

Work was done to determine the rate of sludge buildup at the above rate of loading. This buildup, which has an important bearing on the size and operation of a lagoon, was found to be as follows for a one-month period of manure loading in the laboratory: Cattle, trace; hogs, 1 mm; chickens, 3 mm.

E. Farmstead Planning

1. Chore time standards. At St. Paul, Minn., basic work in cooperation with the Minnesota Agricultural Experiment Station on establishing time standards for farmstead operations has been concerned with a search for a suitable standard for coordinating data taken under differing conditions, as well as the establishment of the actual standard data. Thus far the search for a suitable basic standard for coordinating data has been unsuccessful. In lieu of such a standard, Industrial Engineering standards are being used. The researcher's ability to rate the performance is being utilized for the elements not suited to those standards. The standards established thus far have been for the handling of baled hay, herringbone milking room operations and tractor and trailer operations. To be most effective and useful, standard times will have to be established for all farm work elements and be set up into a complete schedule. The work on this project is continuing in that direction.

2. Farmstead model layout studies. Also at St. Paul, work has continued on the use of models for analyzing the effectiveness of farmstead layouts. Previous work with models has shown that they present an excellent rapid visual picture but not a factual basis for selecting one layout out of a possible three or four that might appear to be of equal value. The final selection of the best layout is dependent upon some other factual method of selection still to be determined. The supply and variety of models completed thus far appear to be satisfactory for analyzing present concepts of dairy farmstead operations. For new and different ideas, new models will have to be developed. Initial attempts to analyze other types of livestock enterprises indicate a need for an almost completely new supply of models. Use of the models has shown a plastic film imprinted with a suitable scale grid and overlaid with a 1/4" Plexiglas sheet to be the most satisfactory base for study purposes.

3. Expansion of urban developments into agricultural areas. At Davis, Calif., in cooperation with the California Station, information on rural code and zoning problems generated by the continued expansion of urban populations into formerly agricultural areas was developed and submitted to the Western Regional Farm Building Plan Exchange Committee.

4. Layouts for handling wafers on large farmsteads. Also at Davis, preliminary, exploratory studies on efficient arrangements for transportation, storage and feeding of hay wafers on large California farmsteads have been started.

F. Fallout Protection

At Beltsville, Md., the new man-made threat to agricultural productivity, radioactive isotopes, necessitated investigation into means for protection of farm animals and their caretakers from gamma rays. At the request of FES and in cooperation with OCD, protective structure designs were studied, two plans were developed, and manuscript material for a bulletin on fallout protection was prepared. The two plans illustrate concepts of: (1) a family shelter adjacent to the livestock, (2) a multi-use shelter to offset some shelter expense by daily production, (3) a shelter that is used daily so the operation within the shelter will be familiar routine, (4) a shelter with permanent shielding, and (5) emergency standby equipment for self-sufficient operation.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

A. Meteorological Factors

None

B. Construction Standards

Teter, N. C. 1962. Report of construction standards committee. Presented at Summer Meeting, ASAE, Washington, D. C., June.

Teter, N. C. 1962. Minimum structural standards for rural housing. Presented at Western Region Meeting of the Plan Exchange, Jackson, Wyoming, July.

Yeck, R. G. 1962. Codes and standards for fire safety in farm structures. Presented at Farm Fire Safety Seminar, Huntley, Illinois, September 27.

C. Materials and Construction Methods

Liu, R. C., Teter, N. C., and Kent, T. E. 1962. Use and performance of sheet strips warped to approximate a hyperbolic paraboloid roof. Transactions of the ASAE, V. 5, No. 1, pp. 68-74.

Kent, T. E., Liu, R. C., Teter, N. C., and Meador, N. F. 1962. Grout surfaced, insulated, stress-skin panels for farm buildings. Transactions of the ASAE, V. 5, No. 2, pp. 165-167, 171.

Kent, T. E., Teter, N. C., and Liu, R. C. 1962. Farm building panels. USDA, ARS 42-65, August.

Three utility trusses--lap nailed construction. 1962. (Exchange Plan Nos. 5921, 5922, and 5923). USDA Misc. Pub. No. 909, August.

Kent, T. E. 1962. Broiler housing - an argument for better construction. Proc. of 1962 Broiler Housing Seminar, University of Delaware, Georgetown, Delaware, September.

Teter, N. C. and Ota, H. 1962. Insulating materials and vapor barriers--their value and application. Proc. of 1962 Broiler Housing Seminar, University of Delaware, Georgetown, Delaware, September.

Christmas ornament inspires design for new farm buildings. 1962. USDA, Agricultural Research, page 14, December.

Kent, T. E., and Dowdy, P. L. 1963. Use clear-span roof trusses. Hoard's Dairyman, pp. 210-211, February 25.

D. Water Supply and Wastes Disposal

Eby, H. J. 1962. Manure disposal lagoons. Presented at Symposium on Industrial Waste Control, Washington College, Chestertown, Maryland, May 5.

Jones, E. E. 1962. Measuring water use. Water Well Journal, August.

Eby, H. J. 1962. Design criteria and management for manure lagoons. Agricultural Engineering Journal, December.

Rockey, J. W. 1963. Water requirements and treatment for the home and farmstead. Agricultural Engineering Journal, January.

E. Farmstead Planning

Larson, R. E. 1962. Traffic patterns of animals, people, vehicles, feed and materials. Presented at Farmstead Planning and Mechanization Workshop, University of Illinois, Urbana, Illinois, December 4.

Cleaver, Thayer and Kelly, C. F. 1962. Drylot feeding facility design for California. Presented at Winter Meeting, ASAE, Chicago, Illinois, December 11-14.

F. Fallout Protection

See publication, Area 7C.

AREA NO. 11: ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR INSECT CONTROL AND OTHER FARM USES

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. The use of chemicals in agriculture is increasing rapidly with United States pesticide sales increasing every year for the past eight years from 161 million dollars in 1953 to 300 million in 1961. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since there is zero tolerance of DDT in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled without using chemicals?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform maturation with increased practicability of once-over harvest programs.

USDA PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of eight States. Electrical and physical methods for corn borer control are studied in Iowa, cotton insect control in Texas, with the project contributing to Regional Research Project S-37, Basic Factors Involved in Control of the Pink Bollworm. Electrical and physical methods

of tobacco insect control are studied in North Carolina and Virginia, and vegetable insect control and light trap design in Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland. Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska, Tennessee, and Washington.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 11.7 professional man-years; of this number 6.4 is devoted to electrical and physical insect control, 4.6 to radiofrequency, glow discharge plasma, and electrostatic equipment for product treatment, and 0.7 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Electric Traps for Vegetable Insects

Research on the use of light traps for controlling insects in home vegetable gardens was continued for the fifth consecutive season in cooperation with the Departments of Agricultural Engineering and Entomology of the Purdue University Agricultural Experiment Station, Lafayette, Indiana. This work was partially supported by a grant from the Indiana Electric Association.

Plots, 60' x 60', isolated 200 feet apart, in which sweet corn, cucumbers, and tomatoes were planted, were subjected to four different lighting conditions as follows: (1) unlighted, (2) five blacklight (BL) lamps in a fan-type trap, (3) five BL lamps in an electric-grid type trap, and (4) five green-photo lamps in a fan-type trap. Also, three different insecticidal applications were provided for cucumbers in the plots, namely: (1) no insecticide, (2) application of dieldrin to time of flowering, and (3) application of dieldrin throughout the season.

The yield from cucumber plants protected from striped and spotted cucumber beetles by a combination of BL lamps throughout the season and insecticide, either throughout the season or until time of flowering, was significantly higher than when the plants were protected by insecticide alone or lamps alone. Similarly, in 1961, cucumber plants protected by dieldrin to time of vining plus a light trap, equipped with either five 15-watt BL lamps or a combination of two 15-watt BL and three 15-watt green-photo lamps throughout the season, yielded as much as unlighted plants sprayed throughout the season and higher than unlighted plants sprayed to time of vining. These findings indicate that it may be possible to reduce the cost of protecting cucumbers from cucumber beetles by using light traps and reducing the number of insecticide applications.

Results from 5 years (1958-62) of similar experiments show that the yield of cucumbers was increased significantly over that of untreated checks when they

were protected from striped and spotted cucumber beetles by one light trap equipped with either three or five 15-watt fluorescent BL lamps. Five BL lamps per trap gave better protection than did three, and BL lamps gave consistently better protection than did green fluorescent lamps and combinations of BL and green lamps.

The 1962 results on the protection of tomato plants from tobacco and tomato hornworms indicated that one light trap, equipped with five 15-watt BL lamps per plot, reduced the percentage of plants infested from 75 percent in the unlighted check to 12 percent, and the average percent of foliage eaten per plant from 6 percent in the check to less than 0.04 percent. No infestation of corn earworms occurred on these tomatoes.

Tests on the protection of sweet corn in 1962 indicated that European corn borer infestation was so slight that no significant damage occurred under any treatment. However, in the late planting of corn, the general population of corn earworms was high and all plots were completely infested.

In cooperation with the Virginia Agricultural Experiment Station and the Virginia Truck Experiment Station, electric insect traps were operated at two tomato canneries in eastern Virginia to determine the relative attractiveness to fruit flies of two different types of lamps. Fruit flies are of significant importance in the tomato canning industry. In 13 nights the trap with a blacklight lamp attractant caught 178,000 fruit flies, which was about seven times greater than the number caught in the trap with an incandescent lamp. Limited investigation will be continued to determine if traps are effective in reducing the number of eggs deposited by flies on tomatoes.

Light traps have been operated the past 10 years near Ames, Iowa, in cooperation with the ARS European Corn Borer Investigations Laboratory and the Iowa Agricultural and Home Economics Experiment Station. Corn borer infestations were relatively low in Iowa in 1962. A total of 8,097 borers was captured in four traps. As in the past, a trap with a single 15-watt BL fluorescent lamp captured more corn borers than any other trap. Traps with 200-watt incandescent lamps captured a higher ratio of male to female borers than did those with 15-watt BL fluorescent lamps. The Extension Service operated four ARS-furnished survey traps in various parts of Iowa in 1962. Reports on the infestation of 15 economic insects based on the light trap catches were furnished to county extension directors and other cooperators. Insect traps will be operated near Ames in 1963 with the same cooperators as in the past.

Corn earworm moths released in a free-flight response laboratory in cooperative work at Purdue University responded to blacklight lamps at lower temperatures than did striped cucumber beetles. Earworm moths caught live in the field using blacklight insect traps were released in the free-flight chamber and were attracted to an energized electrocutor grid using no additional attractant.

B. Electric Traps for Cotton Insects

Laboratory and field studies relating to the use of visible and near ultraviolet radiant energy for attracting and collecting various species of cotton insects were continued at College Station, Texas. This work was conducted in cooperation with the Texas Agricultural Experiment Station and the ARS Entomology Research Division Laboratories at College Station and Brownsville, Texas. This project contributes to Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm."

In the laboratory, a Y-tube test chamber was used in group response with adult boll weevils to determine the relative attractiveness of equal energy, narrow-band stimuli in the spectral region from 315 to 665 millimicrons (mu). Maximum response was obtained for wavelengths in the blue-green (490 to 515 mu) region of the spectrum with decreased response indicated for both shorter and longer wavelengths. Work is continuing to determine absolute energy levels required to induce phototactic responses. Laboratory findings on wavelengths intensity requirements will be utilized in experimental devices designed for attracting and trapping the boll weevil.

Preliminary investigations in cooperation with the Physics Department, Texas A&M College, have shown that presently available equipment and facilities can be used for determining spectral response characteristics of insects with electroretinogram (ERG) techniques. Establishment of successful testing techniques with the ERG method should greatly facilitate response studies which now must be conducted by group response methods. Test insects would be required in much smaller numbers for ERG response studies.

Tests of 15-watt blacklight lamps supplied by two different manufacturers revealed that two types of BL lamps are now in commercial supply channels. One of these lamps has a strong, narrow emission band with peak output at 350 mu, whereas the other lamp has a broad emission band extending into the blue region and peaking at 365 mu. Prior to this year, available BL lamps were of the first type (peak output at 350 mu). Tests will be conducted during 1963 to determine the relative effectiveness of the two types of lamps for attracting insects.

Information obtained from laboratory and field observations of boll weevil movement characteristics was utilized in the design of experimental traps for the boll weevil. Several types of commercially available 15-watt fluorescent lamps with outputs peaking at or near the green region were used in these traps in attempts to trap the boll weevil. Weevils were trapped under laboratory conditions, but all efforts at field trapping were unsuccessful. The need is indicated for further study of intensity, wavelength, temperature, and time-of-day factors as related to induced boll weevil responses.

C. Electric Traps for Tobacco Insects

Laboratory investigations continued in cooperation with the Virginia Agricultural Experiment Station, Blacksburg, Virginia, on spectral response of hornworm moths exposed to different wavelength bands of ultraviolet and visible radiation. Greater responses were obtained to bands in the ultraviolet region. Again, the best response was at a wavelength of 3654 A. Better responses were obtained at 75° F. than at 65° F. and at 80 percent relative humidity than at 70 percent. Similar work will be continued in an effort to obtain a more effective attractant.

A field investigation to determine the effectiveness of blacklight insect traps for population control of tobacco hornworms was conducted near Oxford, North Carolina, in cooperation with the Entomology Research Division, ARS. Results with 324 traps distributed over a 113-square-mile circular area showed that a significantly greater number of moths were caught per trap near the periphery than were caught near the center of the area. An indicated control in excess of 55 percent was determined. Data on hornworm eggs found on tobacco plants also showed that the traps were providing about 50 percent control. This investigation will be continued through the 1963 tobacco-growing season. A similar test is needed on a small island or isolated area to substantiate the results and possibly determine the effectiveness of this technique in combination with other population control measures.

D. Physical Methods of Fly Control for Dairy Farms

Investigations of physical methods for controlling flies in and around dairy barns are being conducted at Beltsville, Maryland, in cooperation with the Animal Husbandry and Entomology Research Divisions, ARS. Construction of a new laboratory building for this research was completed in November 1962 at Beltsville, Maryland. Preliminary studies conducted in temporary facilities at Orlando, Florida, and at Beltsville indicated that blacklight ultraviolet radiation is attractive to both house flies and face flies during twilight periods. Use of fluorescent panels behind the light sources appeared to increase attractiveness.

A successful colony of face flies has been established. Studies are now being conducted to determine the effect of colony illumination levels on face fly egg production, period for development, adult longevity, and adult behavioral responses. Observations were made on the behavior of face flies in the field during twilight to determine characteristics which might be useful in applying controls. Face flies were marked, released, observed, and some relocated after sunset. Test equipment and techniques are being developed to evaluate the attractiveness of visible and ultraviolet radiation to face flies, house flies, and stable flies.

E. Components and Design of Insect Survey Traps

Survey entomologists in nine North Central States continued use of light traps for weekly survey reports on insects of economic importance. Similar trapping programs are being initiated in the Northeast. Use of special light traps for European chafer detection was continued by Plant Pest Control Division, ARS, resulting in the establishment of new quarantine areas for the European chafer in nine counties of New York and two counties of Connecticut, plus the removal of quarantine from West Virginia. Improvements of equipment for operating chafer traps in isolated areas are continuing.

Initial trials of blacklight traps for capturing brown-tailed moth and winter moth in New England were successful, so use of more traps is planned for survey purposes. Tests with fruit insects were attempted at the Ohio Station.

Improved designs for a portable 6-watt trap for use in isolated locations and a 15-watt trap for use in more permanent installations such as ports of entry are being developed in conjunction with Plant Pest Control Division and interested manufacturers for trial at several field stations.

Trials were continued in Indiana to study the effect on light trap catches of the following component features: funnel size, placement and wattage of circline lamps, type of blacklight phosphor, and cyclic operation of the attractant lamp (30 minutes on--30 minutes off). A new trap of commercial design being considered by Plant Pest Control Division for survey applications was compared with survey traps of known performance. The new trap was equally effective for survey sampling.

Effectiveness of traps was evaluated both on the basis of the total number of insects collected and on the variety of orders and species of economic importance included in the collections and the numbers of each represented. Further field work will be necessary before definite conclusions can be drawn on the component trials.

Experimental traps were used in Texas for comparison of two lamp mounting methods; namely, (1) high mounting--to irradiate area around base of trap, and (2) low mounting--to prevent irradiation of area around base of trap. Evaluations based on numbers of insects collected showed no advantage for one method over the other. Further study is needed to evaluate the effect of the two methods of lamp mounting on the numbers of insects alighting and resting in the vicinity of the trap.

A small deflection cone suspended in the lower portion of the trap funnel has been considered essential to the proper functioning of the collection can moisture drainage system. Tests showed that the use of this cone results in a slight but not significant decrease in catches of cotton bollworms,

cabbage loopers, and insects in general. Based on these results, the deflection cone apparently should remain a design feature of the survey trap in order to afford maximum protection from moisture damage to collections.

An improved design for fastening collection containers to traps was developed. In the design, which utilizes spring-action fasteners, the bottom portion of the collection container is held in position against a soft polyurethylene gasket by the spring tension of the fasteners. The fasteners are not position-sensitive, enabling the trap operator to remove and attach the can with a minimum of effort.

An experimental trap design utilizing collection can trays with screen bottoms of different mesh sizes was evaluated. Operation of this trap showed the need for changes in moisture removal system and method of can attachment. Also, with the screen mesh sizes employed (two and six openings per inch), the separation of insects according to size was not adequate. Separation was also influenced considerably by the position of killing agent containers within the can and the strength of the killing agent.

Work with a tripod made of 1/2-inch thin wall conduit indicated that the new design provided adequate strength for use in supporting survey traps. The new tripod is lighter in weight, easier to assemble, disassemble, and transport, and costs less than tripod supports constructed of galvanized iron pipe.

Performance tests were conducted on a transistorized inverter designed specifically for operation of survey traps equipped with 15-watt BL fluorescent lamps. This power supply (manufactured commercially) adequately incorporated design and performance requirements recommended in 1961 to the Plant Pest Control Division, ARS, by personnel of the Farm Electrification Research Branch. This unit provides from two to three nights of automatic trap operation from a fully charged 72-ampere-hour automotive-type battery, is very compact, and operates satisfactorily over a wide range of ambient temperatures.

During the last two years a large room in one of the Purdue University buildings has been modified and equipped to provide a laboratory facility large enough to permit free-flight observations on insects subjected to light attractants. Tests were begun to study the response of striped cucumber beetles, mosquitoes, and corn earworm moths under both controlled environmental conditions and reasonably normal flight conditions in the free-flight response laboratory.

Released test insects flew about the room in a random pattern without their flight appearing to be adversely affected by the physical factors of the room. This indicates that the size and shape of the room and air movement should be satisfactory for free-flight tests.

F. Electromagnetic Radiation Equipment for Seed Treatment

1. Radiofrequency Energy for Vegetable Seed Treatment. Effects of radiofrequency (RF) treatment on germination of several different vegetable seed lots were tested in cooperation with the Asgrow Seed Co. Treatment was found to accelerate the germination of several lots of spinach seed. Emergence from soil in greenhouse tests was also very noticeably speeded up. Two lots of tomato seed tested also showed increased rates of germination. The germination for an okra seed lot was substantially increased by treatment which reduced the percentage of hard-seeds. Work will continue on evaluation of RF treatment for improving vegetable seed germination.

2. Radiofrequency Energy for Insect Destruction and Seed Treatment for Grain and Forage. Investigations of potential use of radiofrequency (RF) energy for insect destruction and improvement of seed germination were continued in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperation on some phases of the work was furnished by the Crops Research Division, ARS, USDA; Eastern States Farmers' Exchange, Inc., Buffalo, New York; the Research Department of the Asgrow Seed Co. and the University of Idaho.

Experiments with stored-grain insects continued to show that all developmental stages of several species were controlled by treatment of infested wheat for a few seconds. The treatments did not damage the germination of wheat if the moisture content was low enough for safe storage. The exact nature of the lethal action has not been determined, but selective heating of the insects in the radiofrequency electric field appears to be a likely explanation. Treatments produced marked weight losses in the insects. High field intensities were generally more effective than low field intensities in killing insects. Treatments at frequencies of 10 and 40 megacycles were about equally effective in controlling dermestid larvae and adult rice and granary weevils when field intensities were adjusted to provide equal heating rates for the two frequencies. Somewhat longer exposures were required to control adult rice weevils and lesser grain borers inside wheat kernels than when the same insects were not shielded by the kernel. Physiological studies on yellow mealworms revealed no differences in amino acids extracted from RF-treated and untreated insects.

Treatments which were very effective in breaking dormancy in DuBois winter oats in 1960 were not damaging to the seed which was retested after 2 years in uncontrolled storage.

Work will be continued on insect control and seed treatment studies with emphasis on learning basic explanations for observed effects due to RF electric field exposure.

Tests on seed lots of several alfalfa varieties showed that germination was effectively increased by RF electrical treatments which reduced the percentage of hard-seeds. Effectiveness of treatment in lowering hard-seed content increased as seed moisture content decreased. Germination response at frequencies of 5, 10, and 39 megacycles appeared to be about the same. Treatment increased the rate at which the seed absorbed water. Microscopic staining tests revealed no cracks in the seed coat due to treatment. Quality of RF treated seed held up as well as untreated seed after 4 years in favorable storage. Quality of treated alfalfa, red clover, and ladino clover seed remained as good as untreated seed when tested after 2 years in uncontrolled storage, and hard-seed content was lower in treated samples.

Treatment was not effective in lowering hard-seed content of sweetclover seed lots unless they were dried to very low moisture levels.

Radiofrequency, infrared, and glow-discharge electrical treatments of Ranger, Narragansett, and DuPuits alfalfa seed lots were equally effective in reducing hard-seed content, increasing water sorption, and increasing the seed respiration rate. The latter treatment produced accelerated emergence for some samples in greenhouse sand emergence tests.

RF treatment appeared to improve germination and emergence of three Kentucky bluegrass seed lots tested during the year. Emergence of treated samples was higher for a lot exhibiting a high degree of dormancy. The number of seeds sprouted at 5 days was significantly higher for treated samples in the two other seed lots.

Studies will continue to evaluate effectiveness of RF energy for improving germination and emergence characteristics of seed, and efforts will be made to learn the basic reasons for observed effects of RF seed treatment.

3. Glow-Discharge Radiation Treatment of Forage and Grain Seed. Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee, in cooperation with the Departments of Agricultural Engineering and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. In cooperative tests comparing glow-discharge, radiofrequency, and infrared treatment of three alfalfa seed lots containing high percentages of hard-seed, all three types of treatment were equally effective in lowering hard-seed content and producing a corresponding increase in germination. Methods were developed for measuring the conductivity of leachate solutions for alfalfa seed samples. Leachate conductivity, water sorption, and oxygen uptake were increased by all three types of treatment. In addition, glow-discharge treatment accelerated emergence of one variety in greenhouse sand emergence tests.

At Pullman, Washington, in cooperation with the Departments of Agricultural Engineering and Agronomy of the Washington Agricultural Experiment Station,

glow-discharge radiation was also effective in reducing the hard-seed percentage of red clover at both high and low moisture contents. Hard-seed percentages in sweetclover seed lots, however, were lowered only when seed moisture content was very low.

Samples of Kentucky bluegrass seed exhibiting a high degree of dormancy were subjected to ultraviolet and heat treatments in a hot water bath, as well as glow-discharge radiation, at Knoxville, Tennessee, in cooperative studies with Crops Research Division personnel at Beltsville, Maryland. A 180° F. heat treatment significantly increased emergence at both 11- and 27-day counts. These studies will be continued in 1963.

In experiments to help explain changes in soybeans caused by exposure to an electric glow-discharge, Ogden soybeans were ground into meal and used as the protein supplement of a diet fed to rats in an experiment conducted in cooperation with the Nutrition Department of the University of Tennessee College of Home Economics. The animals fed the treated bean meal showed a 15 percent higher gain than the animals fed the untreated meal. The experiment is to be continued using different levels of treatment intensity.

Research continued in cooperation with Crops Research Division and the Washington Agricultural Experiment Station to determine effects of glow-discharge electrical seed treatment on wheat. Field trials on spring and winter wheats have shown no significant differences in emergence or plant height due to treatment, except where the treatment was damaging. A small increase in emergence rate was noted in one spring wheat variety.

4. Radiofrequency Energy for Tobacco Studies. In cooperation with the Crops Research Division, ARS, several lots of tobacco seed were exposed to severe RF electrical treatments to study possible genetic effects. Some treated samples, which suffered greatly reduced germination, exhibited much higher mutation frequencies than untreated samples. Included were twin-shoot, diminutive, variegated, mottled, and male-sterile aberrant forms. Results indicate that radiofrequency energy may provide a new means for altering germ plasm in plants.

In other cooperative studies with Crops Research Division, RF exposures of tobacco alkaloid preparations for times up to 24 minutes were effective in breaking down the ring structure of the alkaloids where heat treatments alone and shorter RF treatments had failed to do so. Further work is planned to investigate the usefulness of RF energy for modifying tobacco alkaloids.

5. RF Energy for Cotton Studies. Limited studies were conducted in cooperation with the Departments of Agricultural Engineering at New Mexico State University and Texas A&M College to determine whether RF treatment might improve germination and emergence of cottonseed. The variety used in New Mexico field tests emerged very well and treated lots showed no

improvement. Significant increases in the number of plants emerging from a poorly germinating seed lot were obtained in tests at the Texas Agricultural Experiment Station. Limited studies will continue on electrical treatment of cottonseed to improve germination and emergence characteristics.

6. Glow-Discharge Radiation Treatment of Cotton Seed. Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee in cooperation with the Department of Agricultural Engineering of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. Glow-discharge electrical treatment of gin-run, machine-delinted, and acid-delinted cottonseed significantly increased germination after 2 days in a laboratory seed germinator. Seedling radicle development for treated gin-run and mechanically delinted seed was superior to the radicle development of untreated seed after 4 days. Results of a 3-year field test conducted in cooperation with Crops Research Division, ARS, at Knoxville, Tennessee, however, revealed no improvement due to glow-discharge treatment of cotton seed.

Acala 1517D cottonseed emerged very well in field tests conducted by New Mexico State University and treated lots showed no improvement. Laboratory emergence tests of glow-discharge-treated cottonseed indicated possible improvement for a poorly germinating seed lot tested at the Texas A&M Experiment Station, but tests were not conclusive.

Earlier research on glow-discharge treatment of cotton yarn revealed greatly increased breaking strength for treated yarn. Studies of effects of treatment on cotton fiber were temporarily suspended this year due to a leave of absence for cooperating personnel.

7. Basic Characteristics of the Glow-Discharge Radiation. Studies were continued at Knoxville, Tennessee, on voltage and current wave forms associated with glow-discharge treatment of seeds. The significance of differences in wave forms noted under different operating conditions has not yet been satisfactorily explained.

Temperature studies in the glow-discharge apparatus have continued at Pullman, Washington, with the aid of encapsuled chemical compounds of known melting points. Information on the temperatures in the discharge tube indicates that, for a given treatment condition, a particular temperature is reached sooner with seeds in the tube than with no seed present. Temperature measurements in the discharge tube will be continued and a study of the relationship between these temperatures and the effects of the treatments will be made.

8. Electrostatic Seed Separation. At Corvallis, Oregon, a study was conducted with the electrostatic machine to determine if seed mixtures that could not be separated with the conventional machines (which sense only the size, shape, length, and density of seeds) could be separated by their differences

in electrical conductivity. The project was terminated in 1962 but the electrostatic machine was used on some twenty problem seed samples, four of which were considered successful. Witchweed seeds were removed from two types of sandy soil; inert matter and seed heads were removed from onion seeds; and pink bollworms were removed from cotton gin trash.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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* Copies not available.

AREA NO. 12: ELECTRIC EQUIPMENT FOR FARM LABOR REDUCTION

Problem. American agriculture produces about 600 million tons of crop and animal products each year. This is more than five times the weight of the total annual steel production in the United States. Most of these products are handled several times, which means a tremendous task of moving material. Development of equipment to decrease labor of livestock chores has been far less rapid than development of field equipment. For example, the production per man-hour for all crops increased nearly 400 percent in the last 50 years while the increase for poultry was only about 250 percent, for milk cows about 150 percent, and beef cattle less than 50 percent. The amount of working time spent on livestock production (estimated to be 3,833 million man-hours per year in 1961) now is 40 percent of the entire farm labor requirement. Equipment to substitute electric energy or tractor power for hand labor for many farmstead operations is now on the market but research is needed to provide flexibility of use in existing buildings and to permit automatic control as well as to extend mechanization to other operations. Because livestock chore equipment may be needed 365 days per year, it should pay for itself more quickly than field equipment which may be used only a few days per year.

USDA PROGRAM

The Department has a continuing long-term program with engineers working cooperatively with state experiment stations, USDA entomologists and other scientists on basic and applied research. Equipment and control for automatic feeding of livestock and poultry is under development in Washington and Illinois State Experiment Stations. Work on performance characteristics of upright-silo unloaders is in cooperation with the Minnesota State Experiment Station. Work on equipment for handling bees and honey is in cooperation with the Apiculture Branch, Entomology Research Division, and the Arizona and Wisconsin State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 5.0 professional man-years; of this number 2.0 are devoted to bee equipment, 2.5 to equipment for livestock and poultry, and 0.5 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Cattle Feeding Equipment

1. Beef cattle equipment. In Illinois, work, cooperative with the University of Illinois Agricultural Engineering Department, has progressed on an automatic cattle feeding system. The current-sensitive silo unloader control has been proved to be sufficiently accurate for normal cattle feeding operations. A cable supported top-unloading silo unloader equipped with two motors, one to power the gathering auger and one to power the blower-

thrower, will deliver grass or corn silage at a constant rate within plus or minus 5 percent of the set amount in pounds per minute. This controller is equally adaptable to single motor unloaders for the purpose of keeping the unloader motor properly loaded. An electric controls manufacturer is developing a control system for silo unloaders using the current sensing method. Also in Illinois a variable speed auger is being used to meter high moisture shelled corn. The variable speed auger removes shelled corn in direct proportion to the auger speed. The final metering rate in pounds per minute is affected by the percentage of fines in the high moisture shelled corn because a high percentage of fines impedes the flow of corn to the metering auger. Power consumption by the meter auger varies widely depending upon the amount of fine material in the shelled corn. A tapered inlet screw 31-inches long was used to load the 5 1/2-inch discharge and metering auger. The auger was kept 60 percent full with this arrangement. At 10 to 100 revolutions per minute the 5 1/2-inch auger discharged an average of 1.31 pounds of high moisture shelled corn per revolution. An average input of .0086 hp. per revolution per min. was required to turn the auger. This was subject to considerable variation. Automatic operation of a sweep auger in the high moisture shelled corn is essential for reliable operation of the metering and discharge auger.

2. Dairy cattle equipment. In Minnesota the performance of electric motors for silo unloaders is being determined in cooperation with the University of Minnesota Agricultural Engineering Department. Two makes of standard late model unloaders were installed in two concrete stave silos filled with wet corn silage. The moisture contents of the silages ran 81 percent and 83 percent on a wet basis. The silages on top of the silos were slightly dried out and the unloaders were able to unload the material. At a depth of five feet from the top, both units ceased to deliver any silage. Power demands by this time had doubled. The speeds of the blowers in both units were reduced by 30 percent and unloading again was possible. The speed reduction and a slight blower housing modification by the manufacturer made possible complete unloading of one silo with one make. In the other unit impeller blades of a different design were installed in addition to the speed reduction to enable complete unloading of the silo.

Performance tests of specially designed capacitor motors would indicate ability to operate unloaders if adequate voltages are maintained. One of the repulsion induction motors now in common use did not meet the nameplate ratings for duty cycle. Use of a silo unloader to feed an Experiment Station beef breeding herd reduced labor costs by 50 percent when the silage was frozen and by 70 percent when it was not frozen.

In Washington an automatic horizontal or trench silo unloader is being developed in cooperation with the Washington State University Agricultural Engineering Department. The cutter unit developed in 1962 was tested with two 32-inch long, 16-inch diameter augers. These larger augers were more

effective than the previous 12-inch diameter augers, removing more than 600 lb./min. of peavine silage. With an input of 2 horsepower the cutter will deliver more than 400 pounds of peavine silage per minute. The major work now in progress is the incorporation of the cutter with suitable conveyors to remove the silage from the silo. This has resulted in the development of an experimental unloader. The present unloader design requires 7 3/4 horsepower. When operational difficulties have been overcome, automatic controls will be added.

B. Apiary Equipment

In Wisconsin the development of mechanical equipment for extracting honey and manipulation of large two-queen hives suitable for use in the North Central states is being developed in cooperation with the University of Wisconsin Agricultural Engineering Department and the Apiculture Research Branch, ENT.

A control system for an electrically heated cappings melter is being developed. A system of two thermostats which control the heaters through a relay is being used to control the temperature so that the wax is brought above the melting point without injuring the honey.

An electrically heated uncapping knife is being developed which will maintain a constant temperature level of the knife for various rates of uncapping. An electronic temperature controller will be used to establish the control requirements.

The nylon cloth strainer having 430 square inches of straining surface has been used and has proved very satisfactory. Two strainers installed in series are used. The strainers are cleaned after three hours of operation during which time approximately 3,000 pounds of honey was strained that had been uncapped with a vibrating knife. Cleaning time is less than 10 minutes. These strainers, used in a system of heaters and coolers, provide continuous flow conditioning at recommended temperature levels.

Time required to fill a 60-pound can with honey is limited only by the tank discharge tube when using a bellows-operated, automatically controlled, filling valve. Restrictions in the valve body have been removed.

Removal of bees from filled honey supers with streams of high velocity air shows promise. A shop type vacuum cleaner used as a blower with a rectangular shaped nozzle having 1/2 square inch of area was used. Further study of various fans and nozzles is planned.

A bee watering device consisting of a large flat pan with a coarse synthetic sponge 2-inches thick floating on top of the water is being used. A cover 3 feet above the sponge surface prevents water contamination from flying

bees. Water level is maintained by a float valve connected to a pressure water system; otherwise, the waterer has no moving parts. A sponge with a coarse cell structure is more satisfactory than one with a small cell structure.

Testing of plastic combs having various cell shapes and made from different materials to determine their acceptance and use by bees for brood rearing and honey storage is being done to explore the possibility of material to be used in hive construction. Round, hexagonal, and square shaped cells have been used thus far. All have been accepted and used by the bees, the round cells being most acceptable. Honey stored in the cells could not be uncapped with a knife due to concave cappings below the cell edge.

In Arizona the development of mechanical equipment suitable for apiary operations in the Southwest is being developed in cooperation with the University of Arizona Agricultural Engineering Department and the Apiculture Research Branch, ENT.

Plastic comb made of polyethylene with 3/16-inch round and 1/4-inch square holes were tested at Tucson and Madison, Wisconsin. Some of these combs were coated with beeswax before placing them in the hive. The results were not conclusive but showed promise enough to further the test with 10 different thermoplastics. These will be tested in 1963 at both locations. Three hole sizes will be used. The object of this work is to find a material that is suitable to the bees and will be a uniform and rigid comb for automatic uncapping.

The patent for the pinned uncapper roller was received and a new design of the roller was made. This machine is being designed to increase the efficiency of operation of the portable extractor.

Painting of hive bodies is a major maintenance problem. Seven paints in a total of 22 combinations were used on hive bodies for a durability test. In 8 months the aluminum paint has failed. Temperature measurements just under the paint showed aluminum the warmest with no difference between white paints.

Studies were made to determine how air circulated in the hive, how air affected the hive temperature and how radiation affected the hive temperature to find better means of protecting a colony from heat and insecticidal damage. The studies were performed under controlled condition where one variable was changed per test. Either cold or hot air blown into the hive changed the temperature at the place of entry quickly but in the rest of the hive it was slow in changing. The rate of circulation in the hive depended somewhat on the strength of the colony and on the hive configuration used in the test. Thermal radiation had very little effect on the hive temperature except areas adjacent to hive wall at place of application. The conclusion was that the circulation of air within the hive is very limited.

Cooperative work with the University of Arizona Entomology Department was performed on shades for the leaf cutter bee. Several shade materials and nesting materials were tested, but due to an infestation of the chalcid fly, the test was terminated without conclusive data that any one material for shade or nest was better than the others. Presently they are making a controlled temperature study on the life cycle of the leaf cutter bee which has value in pollination.

C. Hog Equipment

Tests are currently being conducted in cooperation with the University of Illinois Agricultural Engineering Department and the Animal Science Department to evaluate the quantity of air needed and effect of the point of entry of fresh air into a confinement hog raising building. These tests are not complete at this time. Time controlled and time limited hog feeding studies were disrupted by street construction work and no report is available this year.

D. Poultry Equipment

Also in Illinois an auger feed injector has been placed on field test. It has a 2 1/2-inch o.d. helicoid with a 7/8-inch pitch to force the ground feed into the conveying line. The injector has performed very satisfactorily in the field test. There have been six farmers who, upon seeing the experimental unit, have constructed an auger feed injector and pneumatic conveyor for themselves.

The tests of the auger feed injector thus far completed show that the 2 1/2-inch diameter auger is the best size for a conveyor intended to convey up to 3,000 pounds per hour when turned at 1600 to 2000 revolutions per minute. A 3-inch auger has successfully handled 5,500 pounds when connected to a 1 1/2-inch conveyor pipe. The last convolution of the auger (discharge end) is subject to rapid wear. It must be hardened to give satisfactory service.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Apiary Equipment

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AREA NO. 13: ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

Problem. Research has shown that temperature, light, space, and other environmental factors affect the growth, health, fertility, production, and feed consumption of farm animals. Thus, savings in feed, reduced losses from disease and exposure, and decreased costs of production may justify many environmental improvements. Special, controlled environments are necessary for the proper conditioning of crops like tobacco, sweet potatoes, grain, and peanuts; and are extremely effective in maintaining the quality of stored fruits and vegetables. Current scientific and economic developments indicate that production of vegetables and flowers may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops. Conditioning and safe storage of high moisture grain are major problems for a great many farmers. Use of solar heat to aid in drying offers potential economy in this operation. The lack of available electric energy in remote areas of farms has limited the use of electric devices. Conversion of solar to electric energy at the site for adapting new and more efficient thermoelectric devices to farm application may eventually eliminate this energy shortage.

USDA PROGRAM

A new program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with the Crops Division on basic studies of light and thermal environment and their relation to plants in growth chambers. A continuing basic and applied program is underway in Kansas in cooperation with the Kansas State University on solar energy collection and storage for grain drying and for supplementing heat energy to air-source heat pumps for house heating. Solar energy collection and storage for direct house heating is also underway at Athens, Georgia, in cooperation with the Georgia Experiment Station. Research on equipment for basic and applied studies involving light and thermal environment for poultry is underway at Beltsville in cooperation with the Poultry Branch, Animal Husbandry Research Division. At Athens, Georgia, basic studies are underway involving diurnal variations of temperature, humidity, and air velocity effects on growing broilers in cooperation with the Poultry and Agricultural Engineering Departments, University of Georgia. Basic and applied studies on the use of heat pumps to modify thermal environment for hog production were recently started at Holland, Virginia, in cooperation with the Virginia Agricultural Experiment Station.

The Federal scientific effort devoted to research in this area totals 5.9 professional man-years; of this number 1.3 is devoted to plant environment

equipment, 1.4 to house heating and cooling equipment, 2.0 to poultry environment equipment, 0.2 to swine environment equipment, 0.2 to solar grain drying and conditioning, 0.3 to milk cooling equipment, and 0.5 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Equipment for Poultry Environmental Studies

At Beltsville, in cooperation with the Poultry Research Branch, AH, studies of practical systems of lighting turkey breeding flocks are being completed. These studies show that (1) light intensity, from white incandescent sources, of approximately 1 to 40 foot-candles are satisfactory for stimulating reproduction; (2) abrupt rather than gradual lengthening of photoperiod to stimulate sexual activity is advantageous; (3) a shortened light day of 8 hours or a continuous light intensity during the hours of natural daylight of approximately 0.1 foot-candle of 8 weeks duration, will precondition out-of-season turkey hens for subsequent reproduction; (4) environmental temperature control in winter and spring breeding seasons for Beltsville climate shows no relation between temperature and reproductive performance.

At Beltsville, in cooperation with the Poultry Research Branch, AH, a pilot study was conducted in existing facilities beginning in 1961 to determine the feasibility and problems of maintaining birds on a subcircadian 18-hour cycle. One hundred and sixteen hens were divided equally into a 24-hour cycle and an 18-hour cycle group. There were little or differences in percent hen-day egg production between the two groups. Data on time of oviposition for the 18-hour group indicated that more than half the eggs were laid during the dark period of the cycle with a peak during the early part of the dark cycle. Equipment for determining exact time of lay was experimentally used on cages of 20 birds over a period of 5 months.

In 1962 a larger facility was revised to house 300 birds where temperature is maintained at approximately 62° F. during the light period and approximately 75° F. during the dark period.

Selection for the second year's study was on the basis of response to 18-hour cycle. Control birds are maintained on a 24-hour cycle.

Equipment for automatic recording of time of lay by individual birds is planned and a control facility for continuous maintenance of a 24-hour group is in preparation. Experimental pilot studies of automatic recording of time of lay by individual birds resulted in accuracies of 75 percent. Cages and egg sensing devices are being modified to attain higher accuracy.

B. Equipment for Swine Environmental Studies

In cooperation with the Virginia Agricultural Experiment Station hogs were grown in controlled environment from weaning to market weight utilizing heat

pumps with approximately 3 to 1 electric energy conversion efficiency. There were no significant differences in gain per day or feed efficiency between the temperature controlled house and the conventional house.

In cooperative work in California, final analysis of data collected during a study reported last year, relating electrical energy consumption for air-conditioned livestock shelters to cooling indices, provided useful information for predicting operating costs. Cooling degree-days calculated from the mean daily dry-bulb temperature gave satisfactory correlations with energy use (by regression analysis), and have an additional advantage of being easily computed from readily available data. By combining all air-conditioning units used in the four separate studies on the basis of kilowatt-hours used per compressor horsepower and relating to cooling degree-days computed from mean daily dry-bulb temperatures, very good correlation was obtained ($r = 0.775$). The prediction equation obtained for energy use can tentatively be extended to cover possible applications to other types and sizes of air-conditioned farm buildings. The California Agricultural Experiment Station Department of Agricultural Engineering was an active cooperator in the livestock shelter air-conditioning study.

In continued ionization studies, three ion houses 8 x 5 x 4 feet were installed in the hog barn. Air for each house was introduced through a side wall, past ion generating equipment, and exhausted through the wire mesh floor. The air in each house had a different ion treatment, excess positive ions, excess negative ions, or natural conditions. Two tests were completed (a) May 29 to August 20 with pigs starting at about 62 pounds and ending at about 170 pounds, and (b) December 18 to March 6 with hog weights of about 80 pounds to 200 pounds. There were four Duroc pigs per house. The data from neither of these tests has been analyzed but there appear to be little, if any, effects from the treatments.

C. Methods of Cooling Milk on Farms

Preliminary studies were initiated to determine the relation of milk quality to various cooling procedures for on-farm cooling of milk. Initial efforts concern assessments of facilities and equipment by test to provide performance information on installed cooling apparatus. Both ice bank and direct expansion equipment have been calibrated to produce cooling rates of 115, 170, and 340 Btu/hr./gal. Cooling rates are controlled on the ice bank tank by intermittent operation of circulation pump and on the direct expansion tank by modulation of refrigerant flow. The tanks and equipment have been instrumented to record equipment performance factors such as temperatures, refrigerant pressure, electrical energy, and operating time. This work is cooperative with the Animal Husbandry Research Division and the Eastern Utilization Research Division.

D. Plant and Product Environmental Equipment

1. Carbon Dioxide Control in Greenhouses. In cooperation with the Washington State University, Pullman, Washington, equipment and facilities for measuring, recording, and controlling the carbon dioxide concentration is in operation in three greenhouses. The system has been tested for one complete winter and has proved satisfactory. The distribution of CO_2 within the plastic greenhouses varied approximately ± 3 percent from the control set-point. Growth rates of bean plants and production of tomatoes were greatly increased by carbon dioxide levels 3 times normal atmospheric concentrations. Six times normal concentrations produced slightly less increases, although in both levels there was indication of improved photosynthetic efficiency.

2. Plant Growth Equipment and Techniques. Initial studies at Beltsville have concerned improving existing facilities, equipment and controls associated with plant growth chambers. Instrumentation to measure and record performance characteristics of both components and systems is being acquired. Such measurements include temperature, relative humidity, air flow, barometric pressure, light and radiant energy.

Special lamps and light sources for producing far-red radiation were tested for performance. Commercially available lamps require optical filters and special cooling. Efforts are in progress to find satisfactory methods of using these commercial lamps without the losses in desirable radiation accompanying conventional methods of cooling and filtering radiation. Fluorescent type light sources specifically designed for plant growth applications are being compared with standard fluorescent lamps and incandescent lamps in respect to both plant response and lamp performance.

Lamp performance and associated components have been troubled by early failure, improper installation, and rapid deterioration. Factors involved include supply voltage, ambient temperature and ventilation, lack of protective safety controls, inadequate design of lamp and associated components, improper installation and lack of monitor records of performance.

Controls for both lamps and heating-cooling apparatus are being replaced, modified, rearranged or increased to give both performance and protective type action. Monitor information in existing chambers is being secured to establish basis of performance required by plants of growth chamber apparatus. For example, Dunmore type humidity apparatus is being utilized to secure continuous relative humidity levels in growth chambers. Data on permissible relative humidity levels desirable in growth chambers exists only for very limited specific environmental situations.

Light and radiation measurement equipment of laboratory type is being assembled to determine absolute spectral output of various light sources before, during, and after use in growth chambers.

In cooperation with industry, a spectroradiometer is being built for primary use with plant growth chamber lamps and related agricultural applications.

3. Electric Equipment for Soil Warming and Plant Growth. Investigations were begun in Indiana to determine the fundamental requirements for installation and management of electric soil heating cable systems to maintain suitable growth conditions for turf in heavy-use areas. This is in cooperation with the Purdue University Departments of Agronomy and Agricultural Engineering.

Preliminary trials showed that temperatures of 65° F. developed through under-turf heating using electric heating cables produced vigorous bluegrass growth in excess of that desired in a ten-day period in early March 1962, while unwarmed turf remained dormant.

A turf heating installation, 20 x 60 feet, was made in late October. Preliminary results show that, while bluegrass sod remained dormant on unheated soil, root extension was 3 - 5 inches by December 31 on heated areas. Top growth was observed where a plastic cover was used in addition to supplementary heat and in uncovered areas having 10 watts per square foot or more of heat applied. Rooting was more uniform in the plastic covered areas with wintertime desiccation of leaves reduced so that turf remained essentially a normal green even at extreme low temperatures.

4. Environmental Equipment for Potato Conditioning. In Minnesota, in cooperation with the Agricultural Engineering and Horticultural Department and the Facilities and Transportation Branch, AMS, the performance requirements and development of electric equipment for environmental control of potatoes for processing are being studied. Eight 300-pound lots of Irish Cobbler, Pontiac, Kennebec, and Snowflake potatoes were stored in respective 40°, 45°, and 50° F. temperature rooms. The AMS cooperators are interested in determining the varieties most suitable for processing and the optimum holding and/or conditioning environment for each variety for storage periods of one to eleven months. Lots from the 45° and 40° rooms are moved to a 60° conditioning room for the last month before processing. Each month a 300 lot of each variety from each room was processed into flakes and slices. A standard refrigeration unit with a 300% oversize cooling coil was installed to prevent coil freezing. It was difficult to maintain the 40° to 45° F. rooms at the desired temperature because excessive air leaks in and out of the rooms.

E. Solar Heating and Cooling Equipment

1. Equipment for Solar House Heating. At Manhattan, Kansas, in cooperation with the Kansas Agricultural Engineering Experiment Station and industry, work continued on performance studies of heating, cooling, and ventilating equipment supplemented with solar radiation collectors. A solar-supplemented heat pump in a farm residence operated for three years continued to show

higher performance efficiency of about 15 percent. Such improved efficiency results in total lower operational costs of heat pumps by about twice the increase in efficiency amounting to more than 25 percent less operational cost.

In Georgia, collected solar heat supplied 36 percent (range 0 to 100 percent) of the average daily heating requirements of a test house during the winter of 1961-62 at Athens. The collector-storage is designed as a separate unit where it would not be economical or feasible to remodel the house for most effective use of solar heat. The efficiency of such a unit cannot be expected to approach that for a system where the house, collector and storage are designed and built integrally, especially for solar heating. Thermistor control of the collector-storage blower gave better operation than the infrared control formerly used. No. 1 terrazzo chips were not satisfactory for storing heat as the sharp feathery edges crumbled and the resulting dust increased airflow resistance. Washed creek pea gravel used in 1962-63 is performing better. Small size rocks are more effective as they have greater surface area and absorb and release heat faster than large sizes. Data for this season are being analyzed and results will be published next year.

2. Solar Equipment for Grain Drying. The results of three years (1960, 61, and 62) of fall in-storage drying tests of sorghum grain have shown that a solar supplemented system resulted in a saving of 55, 77, and 48 percent, respectively, in energy costs as compared to the natural air drying system. No additional heat was needed by the solar supplemented system. However, the natural air system required added heat from liquefied petroleum source during the 1961 tests.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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Carbon Dioxide Control in Greenhouses

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Equipment for Solar-House Heating

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Solar Equipment for Grain Drying

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Equipment for Swine Environmental Studies

Hahn, L.; Bond, T. E. and Kelly, C. F. 1962. The Relation of Cooling Indices to Electrical Energy Consumption of Air Conditioned Farm Structures. ASAE Paper No. 62-933. Presented before American Society Agricultural Engineers, Washington, D. C.

* Copies not available.

AREA NO. 14: FARM ELECTRIC SERVICE AND RESEARCH INSTRUMENTATION

Problem. Farms east of the 100th meridian used twice as much electricity in 1959 as they did in 1950 and three times as much as they used in 1945. Increased use has forced many farmers to rewire or partially rewire their farmsteads at considerable cost. Overloading of installed wiring results in poor equipment performance, energy losses in the wiring, and creates a fire hazard. Transformers burn out or must be replaced due to overloading. There has been no good method of predicting when a transformer should be replaced and many power suppliers are faced with the problem of finding a simple, effective one. These problems are expected to become increasingly acute as farmers install additional electrical equipment such as house heating units, air conditioning, milk coolers, motors for feed processing and distribution, and irrigation pumps.

Today's technology in farming, as well as research, requires accurate instruments for measuring or monitoring processes such as grain and forage drying and plant and animal environment. Current agricultural research is especially dependent upon accurate instrumentation; some problems require completely new kinds of instruments. Studies are necessary to determine the accuracy and practicability of instruments for many kinds of agricultural measurements.

USDA PROGRAM

The Department has a program involving agricultural and electrical engineers to develop an improved method of estimating the maximum electrical demands of farms. This program is in cooperation with the Iowa Experiment Station, the Rural Electrification Administration, and power suppliers in Iowa, Montana, Minnesota, North Dakota, Wisconsin, Kentucky, and Alabama. Data on energy consumption and electric equipment used on farmsteads are analyzed to predict electric demands by farms situated under similar conditions. Variations in electric equipment due to different crops, farming enterprises and weather require that studies also be made in other areas.

At Beltsville a program is underway to develop and provide accurate, practical and sometimes complex instrumentation for specific program needs. Current work includes cooperation with Animal Husbandry Research Division on nondestructive measurement of fat and lean on live animals.

Federal scientific effort devoted to research in this area totals 3.2 professional man-years. Of this number 1.2 is devoted to energy distribution and farm electric demand, 1.7 to instrumentation and 0.3 to program leadership.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Energy Distribution and Farm Electric Demand

In cooperative work with the Iowa Agricultural and Home Economics Experiment Station, power suppliers, the Rural Electrification Administration, and members of the Farm Wiring Committee of the American Society of Agricultural Engineers, a method of estimating the required transformer sizes for individual farms is under development. This method makes use of multiple-regression equations in estimating the maximum demands of consumers. Demand predictors are energy consumption and the major appliances owned. Coefficients for multiple-regression equations were calculated from data collected for this purpose on 714 farms in 8 northern and central states. These equations and a related transformer-sizing procedure are now being field tested by three power suppliers. Analysis of data from Alabama shows that the maximum demands of farms in this state cannot be accurately estimated by the equations developed for Northern and Central United States. Coefficients for two equations were calculated from the Alabama data, one for farms without and one for farms with electric house heating. Satisfactory estimations of the maximum demands of Alabama farms can be made by use of these equations.

The demands and connected loads of the buildings on 103 farms were tabulated as part of a national farmstead wiring study. The objective of the study is to determine factors which may be applied to the connected loads of farm buildings in sizing service entrance equipment. The demands of several hundred additional farms are now being metered. The incomplete information indicates that a demand factor of approximately 0.5 may be applied to connected loads in excess of 10 kw. Approval and publication by the National Electrical Code of the findings of this study will result in reduced wiring costs for many farms without increasing the risk of fire.

Further work includes the completion of the study of required service-entrance capacities of farm buildings, the development and test of transformer sizing procedures with special attention to farms in the South and to consumers with low energy consumptions, and an analysis of voltages and wiring methods for distributing electricity on farmsteads.

The addition of one silo unloader and a bunk feeder adds nearly ten horsepower to the connected load of a farmstead wiring system. Many new installations add two or three times this amount. The use of 480 volts to operate these additions seems worth considering. Our explorations in this area have brought to light many new complications. Many state codes (Minnesota included) limit voltages to ground on single-phase services at 150. This rules out 440-volt, single-phase motors. In addition, single-phase motors rated for this voltage would have to be a specialty item, at least at the beginning.

The same state codes limit three-phase industrial service voltages to ground at 300. This would dictate a Wye connection of the three transformers. The distribution line serving the Agricultural Engineering farmstead is a Delta system with a midpoint ground on one transformer. The only way to meet the voltage limitation to ground would be to operate with a phantom center ground. This is not compatible with the other service connections on the line.

The use of 480 volts for distribution and a step-down to 240 volts at the silo are now being investigated. This possibly would be allowed by the Minnesota code.

A mechanical problem has arisen in connection with grounding a three-phase motor on a silo unloader. All standard transition devices come with three slip rings. What few three-phase motors have been sold have been grounded through the metal housing part of the transition piece. Safety specialists would prefer an extra slip ring or a ball bearing connection in the transition.

B. Research Instrumentation for Livestock

At Beltsville in cooperation with the Meats Quality Laboratory of the Animal Husbandry Research Division, ultrasonic measurement techniques for physical composition have been developed for use with swine, cattle, and sheep. Correlations between ultrasonic and actual measurements of composition were 0.7 to 0.9. The ability to measure by ultrasonics depends considerably on experience in interpreting information obtained from the ultrasonic apparatus. Multiple layers of fat and lean provide the observer with a choice of several values from which the true value must be determined.

Ultrasonic backfat measurements of swine are comparable in accuracy to conventional probing methods. Use of ultrasonic measurements in evaluating pigs indicates good possibilities of predicting composition of the mature animals. Practical use of ultrasonic measurement in breeding programs will require considerable additional evaluation in combination with breeding studies and conventional indices of carcass composition.

Longissimus dorsi thickness measurements show close correlation between ultrasonic and check observations both in cattle and sheep. Selected points of ultrasonic measurement show good ability to predict on live animals yields of desirable cuts. Extension of the ultrasonic method to provide profiles similar to existing medical apparatus requires, in addition to additional apparatus, controlled immobility of animals and more elaborate operating facilities.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Energy Distribution and Farm Electrical Demand

Altman, L. B., and Charity, L. F. 1962. Sizing distribution transformers for farms. Paper presented at 1962 Annual Meeting of American Society of Agricultural Engineers, Washington, D. C. June 17-20, 1962.

Altman, L. B., and Charity, L. F. 1962. Studies of farm demands. Paper presented at 1962 Annual Meeting of North Atlantic Section of American Society of Agricultural Engineers, Morgantown, West Virginia. August 19-22, 1962.

Altman, L. B. August 1962. Automatic livestock waterers. USDA Leaflet No. 395.

Research Instrumentation for Livestock

Johnson, E. K., Hiner, R. L., Alsmeyer, R. H., Campbell, L. E., Platt, W. T., and Webb, J. C. 1963. Ultrasonic pulse-echo measurement of livestock physical composition. Presented at the 1963 Annual Meeting of the American Society of Agricultural Engineers, Miami Beach, Florida. June 23-26, 1963. Paper No. 63-325.

Line Project Check List -- Reporting Year April 1, 1962 to March 31, 1963

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl in Area & Sub-Subheading
AEa1	Weed, insect pest, & plant disease control machinery Program leadership	Beltsville, Md.		
AEa1-1	Equipment for application of pesticides, defoliants, fertilizers and seeds from agricultural aircraft	Wooster,Ohio, Forest Grove,Ore.	Yes	3-H-1
AEa1-3	The development and evaluation of equipment for the control of the corn borer**	Wooster,Ohio, Ames,Iowa	Yes	3-C-1
AEa1-4	Develop equipment and techniques for application of insecticides and fungicides to crops by ground machines	Wooster,Ohio, Forest Grove,Ore.	Yes	3-G-1
AEa1-5	A study of agricultural spray patterns and droplet size and their relation to the control of crop pests**	Wooster,Ohio	Yes	3-A-2
AEa1-6	Aerial spray equipment for forest insect control	Beltsville, Md.	Yes	3-I-1
AEa1-11	Equipment for the application of chemicals to the soil for control of soil pests*	Wooster, Ohio	Yes	3-B-1
AEa1-12	Investigations of equipment and techniques for mechanical and chemical control of weeds in crops	Columbia, Mo. Ames, Iowa, St.Paul, Minn.	Yes	3-D-1
AEa1-13	A study of basic factors which affect the behavior of pesticide particles**	Wooster, Ohio	No	
AEa1-14	Farm equipment requirements for improved corn production in the Southeast	Experiment,Ga.	Yes	2-D-1
AEa1-15	Equipment for the above-ground application of agricultural chemicals in cotton*	Auburn,Ala. Shafter, Calif. Lubbock,Tex. Stoneville,Miss.	Yes	3-E-3
AEa1-16	Equipment for soil incorporation of chemicals for cotton pest control*	Stoneville,Miss. Shafter, Calif.	Yes	3-E-2
AEa1-17	New mechanical and/or physical methods for insect control on grain crops*	Tifton, Ga.	Yes	3-C-2
AEa1-18	Developing equipment for practical control of insects on grain crops grown in the Southeast*	Tifton, Ga.	Yes	3-C-3
AEa1-19	Detecting and measuring spray deposits on corn ears and silks*	Tifton, Ga.	Yes	3-C-4
AEa1-20	Mechanical methods of destroying fallen cotton squares*	State College, Miss.	Yes	3-E-1
Charter	Physics of Fine Particles, Pioneering Research Laboratory	Wooster, Ohio	Yes	3-A-1
AEa2	Planting & fertilizing equipment & practices Program leadership	Beltsville, Md.		
AEa2-1	Equipment and practices for pasture and hay land establishment and maintenance	Beltsville,Md. Bushland, Tex. Athens, Ga.	Yes	2-B-1
AEa2-2	Planting and fertilizing placement machinery for cultivated field crops and vegetable crops	Md.,Va.,Mich. Ariz.,Wash,Nev.	Yes	2-A-1 2-E-1
AEa2-4	Equipment for applying liquid fertilizer	Beltsville,Md. E.Lansing,Mich.	No	
AEa2-5	Laboratory studies of the performance characteristics of seeding and fertilizer dispensing devices and equipment	Beltsville,Md.	No	
AEa2-7	Development and improvement of production and cultural machinery for bunch and runner peanuts grown in the Virginia-Carolina areas.**	Holland, Va.	Yes	3-F-1
AE00-1	Equipment and methods for decontamination of agricultural lands affected by radioactive fallout	Beltsville, Md.	Yes	2-F-1
AEa3	Tillage Machinery Investigations Program leadership	Beltsville, Md.		
AEa3-1	Soil dynamics as a factor in tillage tool design	Auburn, Ala. Ames, Iowa	Yes	1-C-1
AEa3-2	Basic studies of disk blades for agricultural implements	Auburn, Ala.	Yes	1-D-1
AEa3-3	Soil compaction by machinery	Auburn, Ala.	Yes	1-E-1

*Initiated during reporting year
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AEa3-4	Design and use of deep tillage implements	Auburn, Ala.	Yes	1-B-1
AEa3-5	Effect of design factors on traction and transport equipment performance	Auburn, Ala.	Yes	1-A-1
AEa3-6	Development of tillage machinery that will reduce soil erosion and runoff	Ames, Iowa	Yes	1-G-1
AEa3-7	Measurement and characterization of physical properties of soil as related to tillage implements and tractive effort	Auburn, Ala.	No	
AEa3-8	Mathematical relationships between forces and deformation in soil	Auburn, Ala.	Yes	1-F-1
AEa3-11	Equipment for transferring soil layers and improving surface soil characteristics*	Stoneville, Miss.	No	
E8-AE-1 (PL 480)	Tractive, stability and safety characteristics of wheel-type farm tractor on steep slopes	Helsinki,Finland	Yes	1-H-1
A10-AE-2 (PL 480)	Tillage methods and implements for mountain farms	Jerusalem, Israel	Yes	1-H-2
AEb1	Farm housing Program leadership	Beltsville, Md.		
AEb1-2	Experimental farmhouses	Athens, Ga. Beltsville, Md.	Yes	8-A
AEb1-3	The effect of selected construction and heat distribution means on environment, livability and climatic response in an expansible farmhouse	Beltsville, Md.	Yes	8-C
AEb2	Livestock shelters Program leadership	Beltsville, Md.		
AEb2-1	Determination of environmental design criteria for poultry house design	Beltsville, Md.	Yes	9-D-1
AEb2-2	Environmental factors influencing development, production & health of dairy & beef animals under controlled conditions	Columbia, Mo.	Yes	9-A-2 B-2,E
AEb2-3	Investigation of environmental factors influencing development, production and health of animals in warm climates	Davis,El Centro & Escalon,Calif	Yes	9-B-1, 9-C-1, 9-C-2,4,5 F,13-B
AEb2-5	Reducing time and labor in caring for dairy animals through improved layout of buildings and yards, and the selection and adaptation of equipment	Davis,Calif College Pk,Md.	Yes	9-A-1 10-D-2, 10-E-3,4
AEb2-7	Livestock shelters for southeast	Tifton, Ga.	Yes	9-C-3,E
AEb2-8	Evaluation & development of equipment & procedures for reducing chemical hazards associated with the control of livestock insects	Kerrville,Tex.	Yes	9-G
AEb2-10	Use of models for analyzing farmstead layouts	St. Paul,Minn.	Yes	10-E-2
AEb2-11	Time standards for farmstead work elements	St. Paul,Minn.	Yes	10-E-1
AEb2-13	Development of prototype environmental cabinet for poultry disease research	Athens, Ga.	Yes	9-D-2
AEb2-15	Environmental stress zones as criteria for design of heating, ventilating and air-conditioning equipment for turkey production	St.Paul,Minn.	Yes	9-D-4
AEb3	Storages & related equipment for farm products Program leadership	Beltsville, Md.		
AEb3-10	Studies of basic factors in design & operation of silos	Beltsville, Md. E.Lansing, Mich.	Yes	7-A-1,2, 3,5
AEb3-11	Development of improved methods, equip. & structures for making, storing & feeding silage in S.E.	Athens, Ga. Watkinsville,Ga.	Yes	7-A-1,4
AEb3-12	Farm storage of high moisture grain	Athens, Ga. Ames, Iowa	Yes	7-A-6
AEb3-13	Silage and other forage density measurement with radioactive isotopes	Beltsville, Md.	Yes	7-A-1
AEb3-14	Pressures of wheat & soybeans on bin walls, floors and structural members	Ames, Iowa	No	
AEb3-15	Structures and related equip. for control of plant environ.	Beltsville, Md.	Yes	7-B-1,2

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AEb4	Farm Building Plan exchange & information Program leadership	Beltsville, Md.		
AEb4-5	Farmhouse plans & information	Beltsville, Md.	Yes	8-A-3,8-D
AEb4-6	Farm service building plans and information	Beltsville, Md.	Yes	7-C,9-A-3, 9-B-3,9-C-7 9-D-5,10-C-7
AEb5-	Materials & construction methods for farm buildings Program leadership	Beltsville, Md.		
AEb5-4	Evaluation of stabilized earth blocks made under high pressure as a farm building material	Beltsville, Md.	Nc	
AEb5-5	Development & evaluation of Portland cement-sand sandwich panels	Blacksburg, Va.	Yes	10-C-1
AEb5-6	Incorporation & application of hyperbolic paraboloid (HP) theory to the struct. use of sheet materials in farm structure roof design	Beltsville, Md.	Yes	10-C-2
AEb5-7	Evaluation of rotational resistance of nailed joints to be used in farm structures	Blacksburg, Va.	Yes	10-C-3
AEb5-9	Influence of housing structures & equipment on air-saculitis & condemnations of broilers	State College, Miss.	Yes	9-D-3, 10-C-5
AEb6-	Farmstead water supply & wastes disposal Program leadership	Beltsville, Md.		
AEb6-2	Farmstead water requirements	College Pk, Md.	Yes	10-D-1
AEc1	Cotton ginning investigations Program leadership	Beltsville, Md.		
AEc1-10	Gin waste collection and disposal	Mesilla Pk.N.M. Stoneville, Miss. Clemson, S.C.	Yes	6-H-1
AEc1-14	Measuring elements of fiber quality as affected by ginning & associated operations	Stoneville, Miss. Mesilla Pk.,N.M. Clemson, S.C.	Yes	6-F-2
AEc1-15	Moisture content of cotton for optimum gin house operation	Stoneville, Miss Mesilla Pk.,N.M. Clemson, S.C.	Yes	6-B-1
AEc1-24	Fundamental mechanisms of nep formation in cotton	Mesilla Pk.N.M.	No	
AEc1-25	Sorting & grouping cotton fiber by length for test purposes at gins.**	Stoneville, Miss. Mesilla Pk.N.M. Clemson,S.C.	No	
AEc1-27	Improving saw gins	Stoneville, Miss Mesilla Pk,N.M. Clemson,S.C.	Yes	6-E-1
AEc1-28	Reducing the degrading effects of weathering in the field & the action of insects & microorganisms on ginned cotton fiber & seed	Clemson,S.C.	Yes	6-C-3
AEc1-29	Investigations of the causes for changes in fiber properties resulting from conditioning treatments of cotton before cleaning & ginning	Stoneville, Miss.	Yes	6-B-2 6-F-3
AEc1-30	Investigation of fiber quality problems related to changes in production & harvesting practices as revealed thru ginning	Clemson, S.C. Stoneville, Miss. Mesilla Pk.N.M.	Yes	6-A-1,6-C-2 6-F-4
AEc1-31	Cotton ginning efficiency and cost	Stoneville, Miss	Yes	6-D-1,6-F-1
AEc1-32	Development of alternative seed cotton cleaning devices and methods based on a thorough evaluation of present equipment	Stoneville, Miss. Chickasha, Okla.	Yes	6-C-1
AEc1-33	Improvement & evaluation of equipment for cleaning lint cotton	Stoneville, Miss.	Yes	6-G-1
AEc1-34	Improving cotton ginning performance through cotton quality evaluations and their relationships to ginning and associated operations*	Mesilla Park,N.M.	No	

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Work & Line Project Number	Work and Line Project	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
AEc1-35	Improving extra long staple cotton ginning means and methods*	Mesilla Pk,N.M.	Yes	6-E-2
AEc1-36	Roller gin adjustment for optimum performance*	Mesilla Pk,N.M.	Yes	6-E-3
AEc1-37	Measurement of raw cotton length for cotton ginning evaluation*	Stoneville, Miss. Mesilla Pk,N.M. Clemson, S.C.	No	
AEc2	Long vegetable fiber engineering investigations Program leadership	Beltsville, Md.		
AEc2-2	Improving processes & techniques for cleaning ramie ribbons	Belle Glade,Fla.	Yes	5-C-1
AEc2-7	Developing harvesting & farm handling equip. for bamboo	Belle Glade,Fla.	No	
AEc2-8	Sansevieria harvesting, defibering, & fiber conditioning machinery & methods	Belle Glade,Fla.	Yes	4-F-2
AEc2-9	Development of improved harvesting & processing machinery & methods for the production of kenaf & other jute like fibers	Belle Glade,Fla.	Yes	4-F-1
AEc3	Equipment for harvesting & farm handling of fruits and vegetables. Program leadership	Beltsville, Md.		
AEc3-9	Equipment & methods for harvesting apples	Wenatchee,Wash. E.Lansing,Mich.	Yes	4-C-1
AEc3-11	Equipment & methods for harvesting & farm handling and packing of cultivated blueberries	E. Lansing, Mich.	Yes	4-C-2
AEc3-12	Equipment & methods for harvesting cherries	E.Lansing, Mich.	Yes	4-C-4
AEc3-13	Equipment & methods for handling & harvesting concord grapes	E.Lansing,Mich.	Yes	4-C-5
AEc3-14	Pre-harvesting practices for increasing the efficiency of mechanized potato harvesting	E.Grand Forks, Minn.	Yes	4-H-4
AEc3-15	Equipment & methods for increasing the recovery of potatoes that are harvested mechanically	E.Grand Forks, Minn.	Yes	4-H-1
AEc3-16	Equipment & methods for harvesting & orchard handling of prunes that are to be dried	Davis, Calif.	Yes	4-C-3
AEc3-20	Equipment & methods for mech. harvesting cling-stone & freestone peaches & apricots	Davis, Calif.	Yes	4-C-6
AEc3-21	Mechanical injury of potatoes-evaluation, causes and prevention	E.Grand Forks, Minn.	Yes	4-H-2
AEc3-22	Equipment & methods for thinning peaches & apples mechanically	E.Lansing,Mich.	Yes	4-C-7
AEc3-23	Engineering cost study of harv. potatoes mechanically	E.Gr.Forks,Minn.	Yes	4-H-3
AEc3-24	Equip. & methods for harv. dates mechanically	Davis,Calif.	Yes	4-C-8
AEc3-25	Equipment and methods for harvesting and field handling citrus fruit*	Lake Alfred,Fla. Davis,Calif.	Yes	4-A-1
AEc4	Farm seed cleaning & handling Program leadership	Beltsville, Md.		
AEc4-4	Seed cleaning research applied to specific problem mixtures	Corvallis,Ore.	Yes	5-A-1
AEc4-6	Cutting & feeding mechanisms for legume & grass seed crop harvesting equipment	Clemson, S.C.	Yes	4-E-1
AEc4-7	Improved techniques for harvesting seed crops	Corvallis,Ore. Clemson, S.C.	Yes	4-E-2
AEc4-8	Development of a centrifugal-pneumatic seed separator	Corvallis,Ore.	Yes	5-A-2
AEc4-9	Electrostatic seed separation	Corvallis, Ore.	Yes	11-F-8
AEc4-10	Optimum moisture content for seed harvesting	Corvallis, Ore.	Yes	4-E-3
AEc4-11	Modification of seed-length separators	Corvallis,Ore.	Yes	5-A-3
AEc4-12	Development of vibratory feeders for seeds	Corvallis,Ore.	Yes	5-A-4
AEc5	Equipment for mechanical cotton production Program leadership	Beltsville, Md.		
AEc5-4	Equipment & techniques for crop residue disposal in cotton production	Stoneville, Miss	Yes	2-C-1

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Work & Line Project Number	Work and Line Project	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Area & Sub-Subheading
AEc5-5	Equipment & methods for optimum seedbed preparation for cotton	Stoneville, Miss. Shafter, Calif.	Yes	2-C-2
AEc5-6	Power requirements of cotton production implements	Stoneville,Miss Shafter, Calif.	Yes	2-C-3
AEc5-7	Synthetic mulches for improving cotton stands	Stoneville, Miss. Lubbock, Tex.	Yes	2-C-4
AEc5-8	Cooperative studies on the effects of production practices on the end use quality of cotton and cottonseed*	State College,Miss. Stoneville, Miss. Auburn,Ala. Lubbock,Tex. Shafter,Calif.	Yes	4-B-1
AEc5-9	Performance tests on mechanical cotton harvesters and components*	State College,Miss. Stoneville, Miss Auburn, Ala. Lubbock, Tex. Shafter,Calif.	Yes	4-B-2
AEc5-10	Reduction of moisture added to sced cotton by spindle-type harvesters*	Stoneville, Miss. Shafter,Calif.	Yes	4-B-3
AEc5-11	Sources of trash in cotton harvesting*	Auburn, Ala. Stoneville, Miss.	Yes	4-B-4
AEc5-12	Plant characteristics affecting the performance of mechanical cotton harvesters*	Auburn, Ala. Stoneville, Miss.	Yes	4-B-5
AEc5-13	Field separation of immature cotton bolls from mature cotton*	Lubbock,Tex.	Yes	4-B-6
AEc5-14	Field handling and storage of machine-harvested cotton*	St.College,Miss. Lubbock,Tex. Stoneville, Miss.	Yes	4-B-7
AEc6	Grain harvesting & conditioning- Program leadership	Beltsville, Md.		
AEc6-9	Harvesting efficiency as affected by cutting tops from corn**	Ames,Iowa	No	
AEc6-10	Effects of heated air drying on grain quality	Ames, Iowa	No	
AEc6-11	Moisture relations in grains as they effect drier design	Ames, Iowa	Yes	5-D-1
AEc6-12	Studies of the drying zone in mechanical grain driers	Ames, Iowa	Yes	5-D-2
AEc6-14	Mechanical damage to corn during harvesting and handling	Ames,"&Experiment,Ga.	Yes	5-D-3
AEc6-15	Permissible time for drying grain using unheated air	Ames, Iowa	Yes	5-D-3
AEc7	Specialized crop production & harvesting machinery Program leadership	Beltsville, Md.		
AEc7-8	Develop. & improvement of peanut diggers & shakers	Holland, Va.	Yes	4-G-1
AEc7-9	Develop. & improvement of tung harvesters & windrowers for optimum effectiveness & efficiency	Bogalusa, La.	Yes	4-G-4,5-F-2
AEc7-10	Development & improvement of equipment & methods of handling tung fruit to storage on farm & to processing mill	Bogalusa,La.	Yes	4-G-5
AEc7-11	Determine engineering requirements for artificially conditioning tung fruit for good storage; and to develop an efficient portable huller	Bogalusa,La.	Yes	5-F-1
AEc7-13	Development & improvement of peanut harvesting & field handling equipment	Holland, Va.	Yes	4-G-2
AEc7-14	Development of improved castor bean production, harvest., hulling and conveying equipment	Stillwater,Okla.	Yes	4-G-3 5-G-1
AEc7-15	Development of a cutter, cleaner, loader type of sugarcane harvester	Houma, La.	Yes	4-I-1
AEc7-16	Engineering studies of factors related to harvesting & farm processing coastal Bermudagrass	Tifton, Ga.	Yes	4-D-1 5-H-1
AEc7-17	Mechanical harvesting Burley tobacco*	Lexington, Ky.	Yes	4-J-1
AEc7-18	Curing Burley tobacco*	Lexington, Ky.	Yes	5-B-1
AEc7-19	Physical properties, forms, & treatments of forage*	Beltsville, Md.	Yes	4-D-2,5-E-1

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Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Line Proj. Incl. in Area & Sub-Subheading
AEd2	Automatic electric controls for farm equipment Program leadership	Beltsville, Md.		
AEd2-1	Development of electric and other labor-saving & honey-conditioning equipment for apiary operation in North Central states	Madison,Wis.	Yes	12-B
AEd2-2	Development of electric and other labor-saving & honey-conditioning equipment for apiary manipulation in S.W.	Tucson,Ariz.	Yes	12-B
AEd2-5	Automatic electric control systems for livestock production	Urbana, Ill.	Yes	12-A-1 12-C,12-D
AEd2-6	Electric equipment for removing & handling silage from horizontal silos	Pullman,Wash.	Yes	12-A-2
AEd3	Elec. equip. for environmental modification and control in farm living & production - Program leadership	Beltsville, Md.		
AEd3-2	Evaluation of electric equipment for reducing pig losses	Lafayette, Ind.	No	
AEd3-3	Study of heat pump and solar energy for air-conditioning of farm homes and other farm buildings	Manhattan,Kans.	Yes	13-E-1,2
AEd3-5	Equipment systems for controlling light & temp. for turkey breeding stock	Beltsville, Md.	Yes	13-A
AEd3-7	Elec. equip. for efficient hog production (including heat pump for cooling & heating hog houses)	Holland, Va.	Yes	13-B
AEd3-8	Design factors for electrically controlled air flow & ventilation equipment in broiler houses	Athens, Ga.	No	
AEd3-9	Relation & control of carbon dioxide & light & effects on plants in air supported plastic greenhouses	Pullman, Wash.	Yes	13-D-1
AEd3-10	Development of electric equipment to provide environmental control for investigations of sub-circadian periodicity in poultry*	Beltsville, Md.	Yes	13-A
AEd4	Application of electromagnetic radiation to plants, animals, & their products & to insects and soils Program leadership	Beltsville, Md.		
AEd4-1	Development of equipment for attracting & destroying economic insects with electric energy in North Central states	Lafayette, Ind.	Yes	11-A
AEd4-2	Use of radio frequency energy for insect control & conditioning of farm products	Lincoln, Neb.	Yes	11-F-1,2, 4,5
AEd4-3	Developing of elec. equip. for attracting and/or destroying economic insects in the S.W. states	Coll.Station, Texas	Yes	11-B
AEd4-4	Develop. of electromagnetic radiation equipment for seed & plant product treatment	Knoxville,Tenn Pullman,Wash.	Yes	11-F-3,6,7
AEd4-5	Development of equip. for attracting,repelling and/or destroying economic insects with physical stimuli in southeastern states	Blacksburg,Va.	Yes	11-C
AEd4-6	Evaluation & development of equip. & physical methods for control of flies & other livestock pests	Beltsville, Md.	Yes	11-D
AEd5	Farm electric equipment performance & requirements & farm electric energy distribution. Program leadership	Beltsville, Md.		
AEd5-1	Determination of electric demand characteristics of farm equipment	Ames, Iowa	Yes	14-A
AEd5-3	Electric milk cooling & handling equipment performance requirements	Beltsville, Md.	Yes	13-C
AEd5-4	Performance tests of unloaders for vertical silos	St.Paul,Minn.	Yes	12-A-2
AEd5-5	The use of 480 volts for distribution & use of electric energy for farm use	St. Paul,Minn.	Yes	14-A
AEd6	Development of technical instruments & measurement techniques for farm production & related electrification research Program leadership	Beltsville, Md.		
AEd6-1	Equipment for non-destructive measurement of fat and lean on live animals	Beltsville, Md.	Yes	14-B

*Initiated during reporting year